United States Department of the Interior

NATIONAL PARK SERVICE
WASHINGTON, D.C. 20240

IN REPLY REFER TO:

SEP 19 1984

Dear Reader:

The enclosed thirteen Integrated Pest Management Information Packages are the first installment in a series of forty-five packages. When completed, these packages will cover the major pest management problems encountered within the National Park Service. The remaining thiry-two packages will be completed by June 1985.

Each package provides brief information concerning the identification, biology, ecology, and distribution of the pest. The emphasis of each package is on population monitoring, establishing action thresholds, and nonchemical and chemical methods for control. In some packages action thresholds are not given because they have not yet been developed. The park resource manager or maintenance employee will have to establish these levels for their particular situation through trial and error.

As new IPM information becomes available concerning the various pests the packages will be updated and forwarded to field personnel. Each package has been stored on a word processor and can be easily modified and updated. In addition copies of these packages can be transmitted via telecommunications to any word processor compatible with a CPT.

Pesticides recommended in the packages are based on current registrations and are subject to change. Mention of a product does not constitute an endorsement by the National Park Service or The U. S. Department of the Interior, nor does it imply its approval to the exclusion of other products.

All pesticide use must be approved by the Director, NPS, prior to application.

We hope these packages will provide sufficient background to field personnel and other NPS employees to develop Integrated Pest Management programs within their parks. As you use these packages and discover means of improving them please contact Michael Ruggiero or Gary Johnston in the Biological Resources Division with your suggested changes. In addition if you require additional information about a particular pest please contact your regional IPM coordinator.

Sincerely,

John C. Reed
Chief Biological Resources Division

Enclosures

NATIONAL PARK SERVICE
INTERGRATED PEST MANAGEMENT
INFORMATION PACKAGES

SEPTEMBER 1984

PREPARED FOR:

Biological Resosources Division
National Park Service
Washington, D.C.

NATIONAL PARK SERVICE
IPM Information Packages

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*XLI and XLV have been combined with the preceeding IPM package.

NATIONAL PARK SERVICE
IPM Information Package

ANTS

Final Report

30 August 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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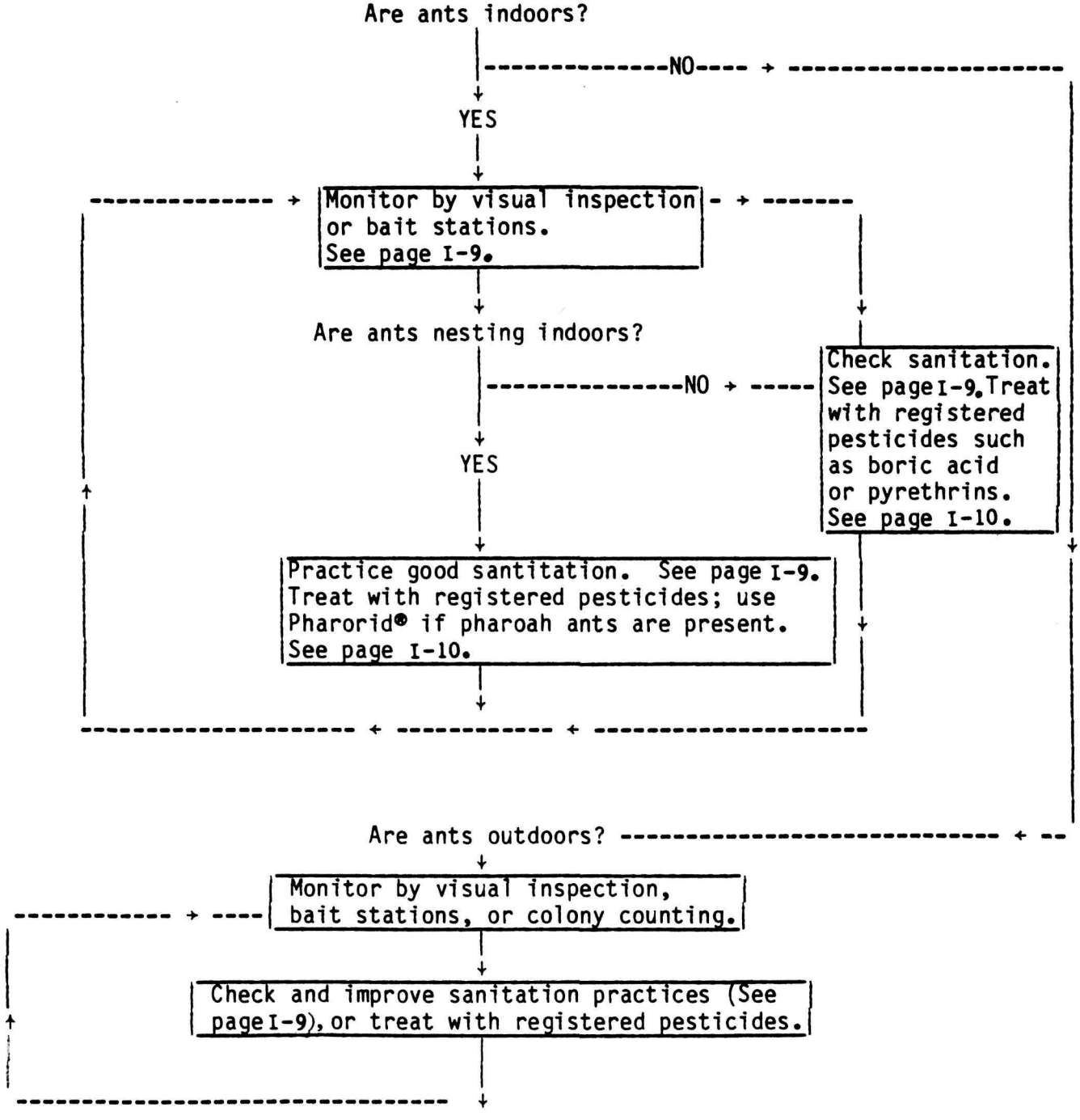
I. ANT IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All uses of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. BIOLOGY AND ECOLOGY OF ANTS

1. Species Described:

The Committee on Urban Pest Management (1980), reported seven ant species to be major pests in various regions of the U.S. (exclusive of carpenter and fire ants discussed in other IPM Information Packages).

See CDC Pictorial Keys to Arthropods, Reptiles, Birds, and Mammals of Public Health Significance, page 119, for a comparative key to common ant species. See also Shetlar and Walter (1982), and Smith (1965), for more detailed keys and descriptions.

A. Pavement Ant - Teramorium caespitum (L)

B. Thief Ant - Solenopsis molesta (Say)

C. Crazy Ant - Paratrechina longicornis (Latreille)

D. Field Ants - Formica spp.

E. Pharaoh Ant - Monomorium pharaonis (L)

F. Argentine Ant - Iridomyrmex humilus (Mayr)

G. Harvester Ants - Pogonomyrmex spp.

2. Geographic Distribution:

A. Pavement Ant - Introduced from Europe, common on Atlantic Seaboard; uncommon inland except in large cities such as Cincinnati and St. Louis; found rarely in California.

B. Thief Ant - Native ant, eastern and central U.S. from Canada to Gulf Coast; uncommon in rest of U.S.

C. Crazy Ant - Introduced from India. Well established in Gulf Coast region, less common further north and inland,, occurring in apartment buildings, hotels, and greenhouses.

D. Field Ant - Several species of native ants, found throughout North America.

E. Pharaoh Ant - Introduced from Old World tropics, found throughout North America in heated buildings.

F. Argentine Ant - Introduced from South America, world-wide. Established in Gulf states and CA. Reported from Arizona, Missouri, Illinois, Maryland, Oregon and Washington.

G. Harvester Ants - Native ants (several species) in warmer and drier regions of South and West.

3. **Habitat:**

A. Pavement Ant - Outdoors, it nests in exposed soil, under objects, or in rotting wood. Indoors it is found around or between lower masonry walls of foundations. Most common indoor nesting ant in eastern U.S. Several thousand in a colony.

B. Thief Ant - Outdoors nests in exposed soil, under objects or in rotting wood. Indoors in woodwork and masonry. Several hundred to a few thousand in a colony.

C. Crazy Ant - Highly adaptable; nests in very dry to moist habitats. Nests found in trash, cavities in plants and trees, rotten wood, soil under objects. Several hundred to a few thousand in a colony.

D. Field Ants - Seldom nests indoors. Outdoors, nests in pavement cracks, along sides of buildings, around trees, under objects. Several hundred to several thousand in a colony. Several species.

E. Pharaoh Ant - Nests in inaccessible places in buildings. Seldom if ever nests outdoors. Colonies extremely large (several thousand to tens of thousands), breed year round.

F. Argentine Ant - Wide spectrum of nesting sites; exposed soil, under objects, rotten wood, tree holes, trash, bird nests, bee hives. Seldom nests indoors. Colonies usually very large (several thousand to tens of thousands),with several queens per nest.

G. Harvester Ants - Nest in yards, around road edges, doorsteps, open woodlands, fields, paths, open soil. Remove large area of vegetation from around nest for colony thermoregulation. Do not nest indoors. Colonies medium to large (several thousand to tens of thousands), several species.

4. **Hosts:**

A. Pavement Ant - Omnivorous; feeds on dead and live insects, honeydew, seeds, plant sap, various foods such as nuts, potato chips, cheese, meats, and grease. Meat and grease preferred. Feeds on wide variety of garden plants; tends subterranean (root) aphids and mealybugs for honeydew.

B. Thief Ant - Omnivorous; predaceous on other ant colonies. Feeds on grain crops. Prefers food with high protein content such as meats and dairy products. Also eats ripened fruit, animal and vegetable fats and oils; tends aphids, mealybugs and scales for honeydew.

C. Crazy Ant - Omnivorous; feeds on live and dead insects, preys heavily on flea and fly larvae and pupae. Feeds on small seeds from gardens (lettuce, tobacco). Feeds on household foods such as meat, grease, sweets, fruit, soft drinks. Tends aphids and scales for honeydew.

D. Field Ants - Predatory on insects, prefers sweets. Some species tend aphids for honeydew.

E. Pharaoh Ant - Omnivorous; feeds on live and dead household insects. Fond of grease, fats and meats. Feeds on bacon, liver, baked goods, syrup. May gnaw holes in silk and rubber.

F. Argentine Ant - Omnivorous. Feeds on seeds, buds, fruit, sap, and sweet plant secretions. Tends scales, mealybugs and aphids for honeydew. Indoors, feeds omnivorously on meats, sweets, dairy products, eggs, fats and oils; prefers sweets. Has been reported to kill young poultry (Shetlar and Walter, 1982).

G. Harvester Ants - Feed mainly on seeds and other plant materials which are gathered and stored in the nest. Aggressive biters; sting readily. Have been reported to kill young livestock. Human deaths from stings have been reported (Shetlar and Walter, 1982). Colonies very long lived (over 10 years) if undisturbed.

5. Life Cycles:

1. Colonies are usually founded by mated queens. Typically, a newly mated queen (after losing her wings) enters or constructs a cavity or cell, closes off the opening and rears a first brood of a few small workers, feeding them from salivary secretions and eggs. The first brood opens the nest and forages for food for the queen and subsequent broods. Workers enlarge the nest, forage for food and tend eggs and immatures. Colonies may take 3-5 years to mature. At maturity, a colony may have several thousand workers and produce winged females and winged males to repeat the cycle again.

2. Some species such as the Pharoah ant form new colonies by budding in which a new queen leaves the parental nest accompanied by a number of workers who aid in establishment of the new colony.

3. In other species, the queen may become a nest parasite, taking over an established colony by entering a queenless colony of the same or other species or killing an established queen. The workers then care for the unsuper queen and her brood.

A. Pavement Ant - Life cycle as (1) above. Winged females usually fly in late June, but have been seen in all months within colonies.

B. Thief Ant - Life cycle as (1) above. Mating flights in late July to early fall. Females frequently carry one or more workers attached to their bodies to assist in colony foundation.

C. Crazy Ant - Little is known about life history, may bud as in life cycle (2) above.

D. Field Ants - Life cycle as (1) above.

E. Pharoah Ant - Life cycle as (2) above. Breeds year round. One colony may have several queens. Workers may forage for more than one colony.

F. Argentine Ant - Mating makes place within colony, life cycle as (2) above. In winter, several colonies may merge and redivide in spring. Several queens may exist in a single colony.

G. Harvester Ants - Life cycle as (1) above, nuptual flights of winged females and males occurs in mid- to late-summer. In winter, colonies are usually sealed and live on stored seeds.

6. Seasonal Abundance:

Most colonies of outdoor ants experience a decline in the number of workers and soldiers during the colder months. Some colonies such as those of the argentine ant may actually increase due to the merging of two or more colonies. Indoor species such as the pharoah ant are unaffected by outdoor temperature and continue to multiply.

7. Responses to Environmental Factors:

A. Pavement Ant - Usually found in urban areas possibly due to lack of competitive ability against other more established or native species in rural areas. Sometimes parasitized socially by another ant species which lacks a worker class and utilizes pavement ant workers to rear its brood (see 5-3).

B. Thief Ant - Native species; well adapted to many climatic conditions.

C. Crazy Ant - Limited by cold temperatures, it is usually found only in heated buildings outside the Gulf Coast region.

D. Field Ants - Native species; well adapted to many climatic conditions.

E. Pharaoh Ant - Limited by cold temperatures, found only in heated buildings.

F. Argentine Ant - Highly adaptable, found throughout the Southern U.S. where it is usually limited by cold temperature. Very competitive with other species, often the only ant in an area. Competes with and preys upon southern fire ant.

G. Harvester Ant - Found only in dry warm areas of South and West; apparently limited by temperature and moisture. Nuptual flights occur after desert rains make ground soft enough for queens to dig earthen cells.

8. Medical Importance: With few exceptions these pest ants have little if any direct medical importance. Some species lack stingers, others are so small to be unable to penetrate the skin with stingers or mandibles. Most of these species are considered pests due to their habits of invading homes in search of food or consuming crop or other desirable plants. By and large they may be considered nuisance pests.

8.1. Direct Effects:

A. Pavement Ant - Reported to sting and bite children causing allergic reaction or rash.

B. Thief Ant - Has been reported to sting and bite, but due to small size, usually not seriously.

C. Crazy Ant - No direct medical effects have been reported.

D. Field Ants - No direct medical effects have been reported.

E. Pharaoh Ant - No direct medical effects have been reported.

F. Argentine Ant - No direct medical effects have been reported.

G. Harvester Ants - Most species are highly aggressive and inflict painful stings and bites. Human and animal deaths from stings have been reported (Shetlar and Walter, 1982).

8.2. Indirect Effects:

A. Pavement Ant - No indirect medical effects were reported. Mainly a nuisance pest species. May contaminate foodstuffs.

B. Thief Ant - Intermediate host of poultry tapeworm. Mainly a nuisance pest. May contaminate food.

C. Crazy Ant - See 8.2.A., Pavement Ant.

D. Field Ants - See 8.2.A., Pavement Ant.

E. Pharaoh Ant - In hospitals, may vector bacteria such as Salmonella, Streptococcus and Clostridium. May contaminate sterile areas such as operating rooms, burn units and pharmacy supplies. May contaminate food.

F. Argentine Ant - Known to transport causitive organisms of dysentery, typhoid fever, and tuberculosis. May contaminate food.

G. Harvester Ant - See 8.2.A., Pavement Ant.

9. Natural Enemies:

Outdoors, ants are preyed upon and parasitized by a variety of organisms. Ants which occur indoors and those species introduced from overseas have few, if any, natural enemies.

III. ANT MANAGEMENT

1. Population Monitoring Techniques:

A. Ants are monitored by visual inspection; foraging workers are rather conspicuous. Columns of workers may in many instances be traced to their point of origion.

B. Bait Stations - Ants in buildings may be monitored by using a bait of preferred food (sweets, grease, peanut butter, etc.) and counting the number of workers visiting the bait for a predetermined time period (1 hr, 6 hrs). Bait stations may incorporate a sticky substance (Tack Trap®, Tanglefoot) so captured foragers may be counted and identified at a later time.

C. Nest Counting - Outdoors, the number of nests per unit of area will give a good indication of the density of colonies.

2. Threshold/ Action Population Levels:

Threshold/action population levels for most ant species are not yet well established. Each park will have different levels of infestation and different tolerance levels within the park. Ants in buildings will be associated with different threshold levels than those outdoors.

3. Management Alternatives - Nonchemical:

The best nonchemical management for ants infesting buildings is good sanitation. All food and beverages should be stored in tightly sealed containers (snap top plastic containers are preferred to screw lid jars; some very small species can move between the threads of lids). All spills and crumbs should be cleaned up immediately and disposed of in tight waste containers. In general, precautions taken against other pests (i.e., roaches) will be effective against foraging ants.

All cracks and crevices which may harbor ants should be sealed and caulked with putty, paint, or petroleum jelly (Olkowski, 1973).

Other sanitation measures include removing vegetation which may harbor ants or support aphids or other honeydew producing insects which may be attractive to ants. Fire wood kept indoors should be regularly inspected for ants. If ants are present, wood should be discarded or burned. Small species of ants (pharoah and thief ants) may be introduced into a building on materials brought in such as boxes and sacks. Areas on the outside of

buildings with exposed wood or cracks in masonry should be inspected and repainted or repaired to exclude ants.

4. **Management Alternatives - Chemical:** Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

A. Conventional Chemicals

The following pesticides are recommended for use indoors on household ants:

- Boric acid
- Carbaryl
- Silica aerogel
- Silica aerogel and Pyrethrins
- Diazinon
- Resmethrin
- Pyrethrins

The following pesticides are registered for use against ants in turf areas (Schwartz, 1982):

- Carbaryl.....3.2 oz/1,000 ft^2
- Diazinon.....2.0 oz/1,000 ft^2
- Chloropyrifos....0.4 oz/1,000 ft^2

B. Nonconventional Chemicals - Methoprene, an insect growth regulator (IGR), has been shown to be effective when used as a component of baits in pharoah ant control. Pharorid®, a methoprene compound registered for pharoah ants, has been shown to be effective in eliminating pharoah ants from hospitals and other areas where other chemical use is not permitted. Liver powder mixed with angel food cake mix is the standard bait matrix (Edwards (1982), Wilson & Booth (1981). Granovsky (1983) has had good results with mint apple jelly as a bait.

IGRs such as methoprene will probably prove effective against other ant species in the future, but at present, they are registered for use against pharoah ants only. Boric acid mixed with mint apple jelly has also shown promising results for pharoah ant control (Granovsky 1983).

5. Summary of Management Recommendations:

1. Indoors - Sanitation to reduce numbers of foragers; caulking and painting to reduce entry points; chemical destruction on indoor colonies.

2. Outdoors - Chemical destruction of nests if necessary, removal of nesting sites, e.g.; old wood or shrubs, removal of obvious food sources and control of honeydew producing aphids.

IV. BIBLIOGRAPHY

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NATIONAL PARK SERVICE
IPM Information Package

Aphids

Final Report

11 January 1985

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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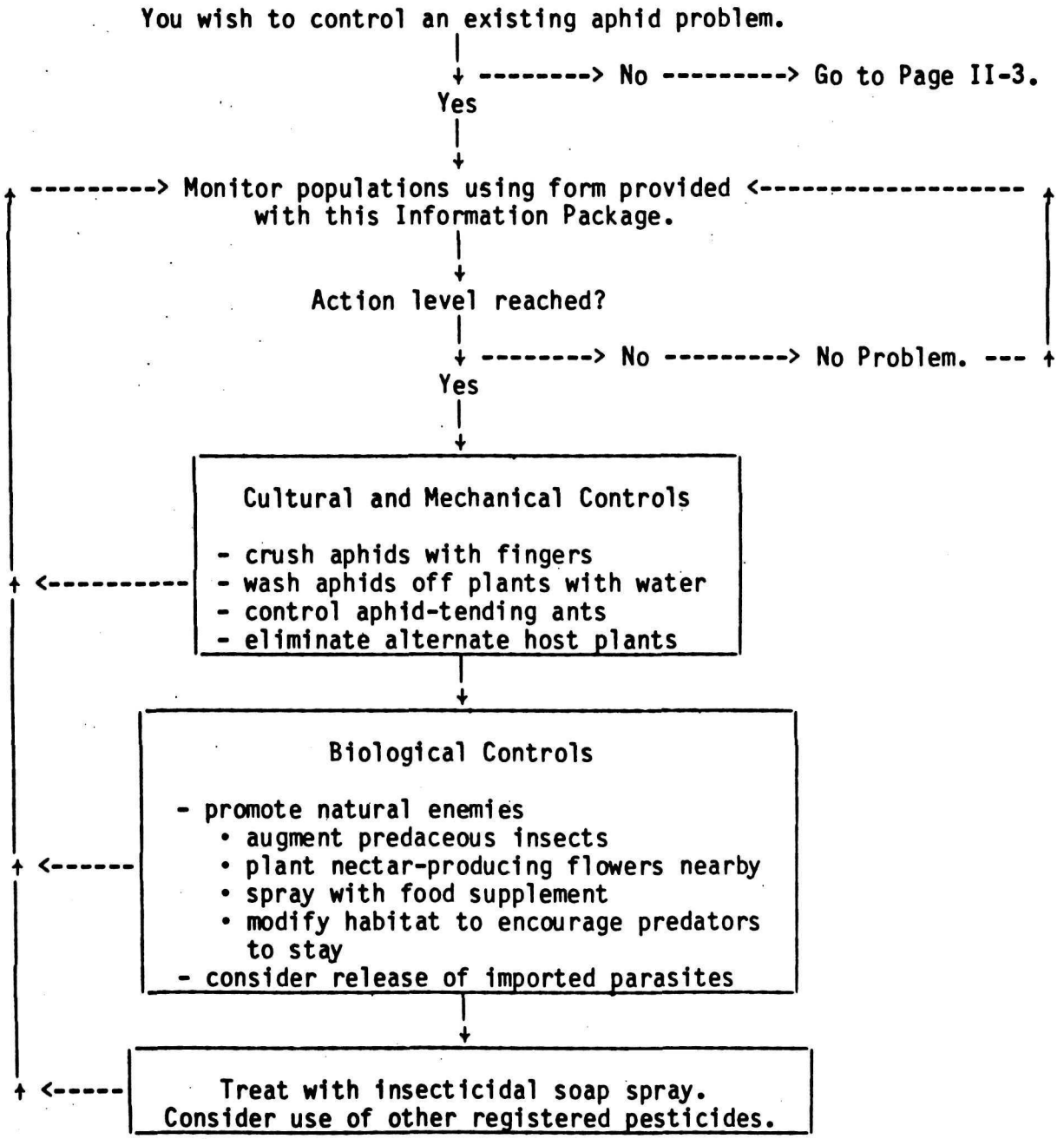
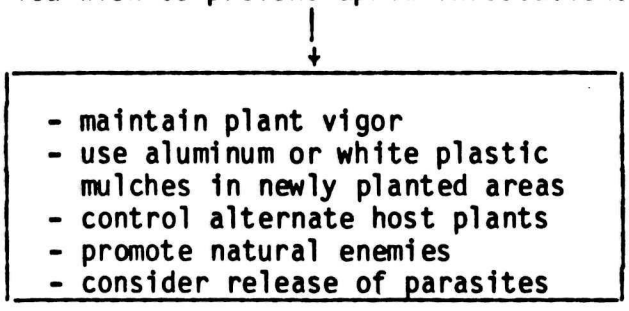
I. APHID IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



You wish to prevent aphid infestation.



II. APHID BIOLOGY AND ECOLOGY

The term aphid is applied to any of a large number of species of small, soft-bodied insects of the superfamily Aphidoidea, order Homoptera. The majority of aphid problems likely to be encountered within the NPS are caused by species in three families: the Aphididae or true aphids and plantlice, the Adelgidae or pine and spruce aphids, and the Phylloxeridae or phylloxerans (M. Stoetzel, pers. comm.). These families comprise thousands of species and include some of the most important plant pests in the world. There is considerable complexity and variation within aphid species; in a single season one species may produce sexual and asexual forms, winged and wingless forms, migratory and stationary forms, and forms which differ in their host plant preferences. Because of the large number of species and the variation which occurs within species, it is recommended that aphid identification problems be referred to your local USDA Cooperative Extension Agent or local state Extension Agent. Color photographs and descriptions of important species can be found in Johnson and Lyon (1976).

1. Species Described:

Aphids are small (usually less than 1/4 inch in length), soft-bodied, pear-shaped insects. They may be pale yellow, green, red, blue, gray, or black, and may have spots or stripes. Winged forms have two membraneous pairs of wings, the front pair much larger than the hind pair. Immature aphids closely resemble the adults, but may differ in color and do not have wings.

Most members of the family Aphididae possess a pair of elongate tubes, called cornicles, on the back of the fifth or sixth abdominal segment. In some species the cornicles are very small or absent. The antennae have six segments. Some species are covered by white, waxy fibers secreted from glands on the body, giving them a thick covering of fuzzy white wax: these are known as woolly aphids.

The Adelgidae, or pine and spruce aphids, lack cornicles, and the antennae are 3- to 5-segmented: all winged forms of these species have 5-segmented antennae, sexual forms have 4-segmented antennae, and wingless parthenogenetic females have 3-segmented antennae. Many species produce waxy threads that cover the body.

The Phylloxeridae, or phylloxerans, also lack cornicles, and in all forms the antennae are 3-segmented. These insects do not produce waxy threads, but some species are covered with a waxy powder.

The balsam woolly aphid, Adelges piceae (Ratzeburg), a member of the family Adelgidae, consists largely of wingless females in North America. The yellow oblong eggs are less than 1/2 mm (1/32 inch) long. First instar nymphs, called crawlers, are active tiny amber-colored insects with red eyespots. They do not have a waxy covering over the body until they have settled down to begin feeding, at which time they become flattened and develop a waxy fringe. Adults are purplish to black, but are usually completely hidden by the waxy threads secreted by the wax glands. They are less than 1 mm (1/16 inch) long. Their legs are very small.

Many species of aphids produce galls on their host plant. Galls are peculiar, distinctive growths that are a response of the plant to certain poorly understood stimuli provided by the aphids. In most cases it is possible to identify the species of aphid that caused the gall by examining the gall. Useful references include Felt (1940), Johnson and Lyon (1976), and Russo (1979).

2. Geographic Distribution:

Aphids are distributed world-wide. Some species have restricted distributions that correspond to the range of their host plants. Hamamelistes agrifoliae Ferris is found only in California where it feeds on coast live oak. Some species are more widespread: the woolly alder aphid, Prociphilus tesselatus Fitch, occurs in the East from Canada to Florida and west to the Mississippi River, and alternates between two hosts within this range: alder and silver maple. A few species, including some of the most significant pest species, are cosmopolitan. The green peach aphid, Myzus persicae (Sulzer), is distributed world-wide.

Many pest species have been introduced from abroad. The balsam woolly aphid, a native of Europe, was first discovered in North America in Maine in 1908, and quickly spread throughout the Applachians from the Maritime Provinces of Canada to Georgia and North Carolina. In 1928 it was discovered in the Pacific Northwest, and now extends throughout the Coast and Cascade mountains from British Columbia to California.

3. Habitat:

Aphids are entirely phytophagous, and as such are most often found on their host plants. Different species show a preference for different hosts, and their habitat is in large measure determined by the distribution of their hosts. Species habitats are further defined by their location on the host plant. Many species are foliage feeders, others prefer tender shoots and stems, some attack the boles of trees, and a few are found on the roots. Some species utilize different parts of the host, their choice being dependent on the season, stage of growth, or the species of host plant.

Gall-forming aphids produce their own highly specialized habitat by causing the host plant to produce the gall within which the aphid lives. Different species of aphids may make galls on different parts of the same species of host plant (Dixon 1973).

4. Hosts:

Aphids feed on a very wide range of plants. Most species feed only on one or a few species of plants. Others will feed on species in a particular family or group of families, and a few species feed on an extremely wide range of plant species in many different families. Plantlice and woolly and gall-making aphids feed on a wide variety of flowering plants, and a number of species feed on coniferous plants. Pine and spruce aphids feed only on conifers, while phylloxerans feed on deciduous plants. The balsam woolly aphid feeds only on firs (Abies spp.).

5. Life Cycles:

Aphids often have very complicated life cycles that involve alternation of host plants, sexual and asexual generations, and winged migrant and wingless sedentary generations. Most species overwinter in the egg stage, and the eggs hatch in the spring into parthenogenetic females that give birth to live young. This may go on for several generations, resulting in very rapid growth of populations. At some point in the life cycle, winged females are produced that migrate to new plants and produce more young parthenogenetically. Then, usually late in the season, a sexual generation consisting of winged males and winged or wingless females is produced. These may migrate again, but whether they do or not, they mate and the females lay eggs that overwinter. The details vary considerably between species.

Balsam woolly aphid populations in North America consist entirely of females. They do not give birth to live young, but instead lay eggs. There are two to four generations per year, depending on the locality and elevation of the population, with fewer generations produced in the northern parts and higher elevations within the range. In populations producing two generations per year, overwintering crawlers begin to feed in late April or early May. The nymphs mature without moving from their initial feeding site, passing through 3 instars before becoming adults in May and June. Egg-laying lasts for about six weeks and totals about 100 eggs; the eggs hatch in 9-12 days. Within a few hours of hatching, the first instars find a suitable feeding site close to the parent, or are blown on the wind or dispersed by other means to another tree to begin a new infestation. Two or three days after inserting their stylets in the bark, the larvae enter diapause lasting 3-8 weeks. After diapause, these nymphs complete development in August or September. The females of this generation lay about 50 eggs, which hatch to produce the first instar crawlers that become the next overwintering generation (Eagar 1984).

6. Seasonal Abundance:

Aphids are notorious for their ability to produce enormous populations during the course of a growing season, with estimates of hundreds of millions or billions of individuals per acre common (Dixon 1973). Aphids may be present throughout the growing season, but each species tends to be most common at certain times of the year. For example, the apple grain aphid, Rhopalosiphum fitchii (Sanderson), is abundant on flowering crabapple only in the very early spring and spends the remainder of the season on grains. Populations of the apple aphid, Aphis pomi DeGeer, build up continuously from early spring when the overwintering eggs hatch, passing through as many as 17 generations to reach a peak in the fall. The balsam woolly aphid is most abundant late in the summer and fall.

7. Responses to Environmental Factors:

The responses of aphids to environmental factors are complicated and varied. The rate of growth and the number of offspring produced (fecundity) are both affected by temperature. There is an optimum temperature that results in the fastest growth with the highest fecundity for each species.

Lower or higher temperatures cause slower growth and lower fecundity. Some species are able to acclimatize to low or high temperatures by raising or lowering their metabolic rate. Not all species have this ability. Aphids that overwinter in an active state are drastically affected by cold weather, and store large quantities of lipoidal materials in their tissues to keep from freezing. This does not protect them in very severe winters, however. Aphids are highly susceptible to rainfall, which can knock them off their host plants. Those on the undersides of leaves or in galls are least affected, those on buds and stems are most affected. The level of precipitation also affects the vigor of the host plant, which affects the aphids feeding on it. However, some aphid species do better when a plant is well watered while others do better if the plant suffers from too little water.

Excessive moisture in cool weather favors the development of entomogenous fungi. Outbreaks of fungal pathogens are more likely to occur in cool, moist seasons than in warm, dry seasons.

Wind may dislodge aphids from their host plant by causing the leaves to rub together, knocking off the insects. Wind also is considered the most important factor in the dispersal of aphids from one plant to the next, as in the case of the balsam woolly aphid, and in the migration of winged forms from one area to another. Because of their small size and weak flight muscles they are not strong fliers and have little control over the direction of their flight when the wind speed is more than a few miles per hour.

The development of winged individuals in a population seems to be triggered by the degree of crowding on the host plant, but the way in which this works depends on the species (Hille Ris Lambers 1966). A single female can produce both winged and wingless progeny as conditions vary. In some species, temperature has been demonstrated to affect the production of winged adults, with more winged aphids produced at higher than at lower temperatures. It is also suspected that day length influences wing development, but it is not clear if photoperiod acts on the aphids directly, or indirectly by altering the chemistry of the plant fluids the aphids feed upon. The chemistry of the plant sap is known to influence

the choice of a host plant, the rate of growth and fecundity, and the development of summer dormant or active larvae. Migrant winged aphids are attracted by yellow, the color of leaves with the most nutritious sap (Kennedy and Stroyan 1959; Auclair 1963). Conversely, they are repelled by aluminum foil and white plastic mulches (Wyman et. al. 1979). Ants have an important role in the development and success of many aphid species (Way 1963). The presence of aphid-tending ants may inhibit the production of winged forms. The ants collect honeydew excreted by the aphids; the ants stimulate the aphids to produce large quantities of honeydew by stroking them with their antennae. Ants protect aphids from parasites and predators, and even transport them to suitable host plants and safe places to hibernate. Some species of aphids live in the nests of their benefactors and are dependent on their ant protectors for their survival.

8. Impact of Aphids:

8.1. Direct Impact:

Aphid feeding withdraws sap from the host plant and can interfere with the physiology of the plant by altering the balance of plant growth hormones. Aphids feeding on leaves can cause yellowing, spotting, and premature senescence, and can reduce the ability of the leaf to photosynthesize by reducing the amount of fluid in the leaf and reducing the surface area as a result of curling. Twigs may develop swelling or gouting. Galls may interfere with the ability of the affected area to function normally and can cause loss of vitality or death of leaves, twigs, or stems.

Symptoms of balsam woolly aphid infestations on fir begin with curling and dieback of the current year's growth, swelling of buds and gouting of shoots, and thinning of the crown. In trees with a heavy infestation on the bole, the wood becomes reddish and coarse, a condition known as "rotholz" or redwood (Knight and Heikkenen 1980). Susceptibility varies with the species: subalpine fir dies within a few years, sometimes before terminal swelling occurs; Grand fir may survive 15 years before dying; Noble fir, Shasta red fir, and white fir may show gouting but usually are not killed. In Great Smoky Mountains National Park, balsam woolly aphids kill Fraser fir in 2-6 years (Allen-Reid 1984).

8.2. Indirect Impact:

As a group, aphids are serious plant pests more because of their role as vectors of plant diseases than because of their direct impacts on their plant hosts. Hundreds of plant viruses are transmitted by aphids. The green peach aphid, Myzus persicae (Sulzer), is the single most important vector. It is known to transmit over 100 virus diseases to plants in about 30 different families (Ossiannilsson 1966; van Emden et. al. 1969). The ability of aphids to transmit plant diseases is related to their piercing-sucking feeding habit, rapid growth, and life histories that involve host alternation and migration.

The vast quantities of honeydew produced by aphids attracts ants, flies, wasps, and other insects which may become a nuisance. Honeydew on leaves, fruit, or other parts of plants may stimulate the growth of sooty mold, which is unsightly and can interfere with photosynthesis. Honeydew also covers cars, benches, picnic tables, and any other objects under infested trees, is annoying to park visitors and is difficult to remove.

Leaf curling, discoloration, and galling may severely reduce the aesthetic and commercial value of ornamental plants.

9. Natural Enemies:

Aphids have many natural enemies, including pathogens, parasites, and predators. The ecology of aphid predators has been reviewed by Hodek (1966), and the impact of the natural enemies of aphids has been reviewed by Hagen and van den Bosch (1968). Reviews dealing with specific groups of pathogens, parasites, and predators of aphids include Madelin (1966), Hodek (1967), Schneider (1969), Stary (1970), Ferron (1978), Hall (1981), Wilding (1981), and Viggiani (1984).

Pathogens of aphids include several species of fungi, primarily in the genera Verticillium and Entomophthora, which are capable of drastically reducing aphid populations under appropriate conditions. Aphids also are susceptible to infection by bacteria, viruses, protozoa, and nematodes, but none of these is known to cause high mortality in natural populations.

Aphids are parasitized by many insects, the most important belonging to the hymenopteran families Aphidiidae and Aphelinidae. The family Aphidiidae

contains over 300 species, all of which are parasites of aphids. In the family Aphelinidae, only species in the genera Aphelinus, Mesidia, and Mesidiopsis parasitize aphids, but certain of these have proven successful in biological control programs. Aphid parasites also are known in two other hymenopteran families, the Encyrtidae and the Mymaridae, and in the dipteran family Cecidomyiidae.

Similarly, there are many insects and spiders known to feed on aphids, including beetles, flies, lacewings, earwigs, and predaceous bugs, among others. Ladybird beetles (Coccinellidae) and green lacewings (Chrysopidae) feed on aphids as larvae and adults, and hence may have a greater impact on aphid populations than insects such as flower or hover flies (Syrphidae) which only feed on aphids as larvae (Hagen and van den Bosch 1968).

Few vertebrates have been reported feeding on aphids, but Smith (1966) reported that in Great Britain birds may have a significant impact on aphid populations under some circumstances.

III. APHID MANAGEMENT

1. Population Monitoring Techniques:

Aphids are best monitored by examining the host plant. On small plants, examine the entire plant; on larger plants and trees, examine representative leaves, twigs, stems, or other portions of the plant. The part of the plant to be examined also will be determined by the biology of the aphid: in the Great Smoky Mountains National Park, balsam woolly aphid infestations are greatest at about 4 meters above the ground rather than at breast height, the standard positon for sampling on trees. Therefore, monitoring populations of this pest is done at this greater height (C. Eagar, pers. comm.). Record data on the aphid monitoring form shown on page II-22. Determine relative levels of infestation as follows (from Heathcote 1972):

Population Density Index -

None	(0)	- no aphids seen;
Very Light	(V)	- one to a few aphids per plant and only a few scattered young plants infested, or one to a few aphids per leaf, shoot, or other section of larger plant or tree and only a few colonies per large plant with the colonies on the young tender leaves or buds;
Light	(L)	- 5-25 aphids per plant and many plants infested, or with many colonies on larger plants or trees, and the colonies not confined to young shoots;
Medium	(M)	- 25-100 aphids per plant and most plants infested, or with large numbers of aphids on larger plants or trees and not in recognizable colonies, but diffuse and infesting many leaves, stems, etc.;
Heavy	(H)	- more than 100 aphids per plant with virtually all plants infested, or with stems, leaves, buds, etc., solidly covered with aphids.

Also survey for the presence and effectiveness of aphid pathogens, parasites, and predators. Aphids killed by fungal, bacterial, or other infections usually remain on the plant and can be recognized by their immobility and peculiar coloration. Parasitized aphids usually are darker than unparasitized aphids, at least near the completion

of the parasite's life cycle. Aphids that have been killed by parasitic wasps are "mummified" - that is, they are darkened and very stiff, and if the adult wasp has emerged there is a round hole in the mummy where the wasp exited. Color photographs of aphid mummies are given in Yepsen (1984). Look for predators among the aphids on the plant, and flying or perching nearby.

2. Threshold/ Action Population Levels:

Because of the economic importance of aphids, threshold/action levels have been established for several aphid-crop systems. However, there is virtually no work of a comparable nature for aphids infesting ornamental plants. In setting threshold/action levels in the NPS, the particular needs of each park must be considered.

Unless threatened or endangered plants are being attacked, control is not recommended in natural areas. Under normal circumstances natural mortality factors will keep aphid populations in check in these areas. If threatened or endangered species are involved the threshold level will be that number of aphids that will interfere with the vitality, reproductive success, and survival of the plant. As a general guide, the threshold level is when the aphid population is medium (see Section 1, above) and fewer than 50% of the aphids show signs of parasitism or disease.

The threshold levels in historic areas may need to be set low if aphids have a significant impact on the aesthetic value of the plants. The park manager will need to correlate aphid population densities with the appearance of ornamental plants and the frequency of visitor complaints, and set the thresholds accordingly.

A further complication arises if aphid-borne diseases threaten plants. If this is the case, the threshold level will be much lower than for aphid damage alone. Accurate identification of both the aphid vector and the disease is essential to be positive that the suspected vector and the disease are causally related. Consult your State University Entomology Cooperative Extension Service for aid in identification of aphids and plant diseases that may be transmitted by them.

3. Management Alternatives - Nonchemical:

Nonchemical alternatives for aphid control include mechanical actions, selection of resistant varieties, and biological control.

The simplest approach to aphid control is crushing them between your fingers. This will work on garden plants and other ornamentals when infestations are light and not too extensive. Another simple approach is to knock the aphids off the plants with a stream of water from a hose or sprayer.

Migration of winged aphids into newly planted areas can be inhibited by the use of aluminum foil and white plastic mulches (Wyman et. al. 1979; Yepsen 1984). These work best with young, small plants up to one foot tall. The highly reflective surface of the mulch causes migrating aphids to become disoriented, reducing the number of migrants that land and become established on the plants.

Successful aphid control has also been achieved by controlling alternate hosts of the pest species (Knipling 1979). For example, to control the green peach aphid in gardens and orchards Yepsen (1984) recommends clearing plants such as plantain, bindweed, and lamb's-quarters from nearby land. See Information Packages VII, IX, XL, XLI, XLIII, XLIV, and XLV for methods to control weeds.

Ants play an important role in the success of aphids (see page II-9). Therefore, control of ant populations often has a significant impact on the control of aphids. If ants are observed on aphid infested trees, apply a commercial sticky substance such as Stickem® or Tanglefoot® in a band around the lower trunk of the tree. In gardens or other situations where individual treatment of plants is impractical, a barrier of bone meal or crushed charcoal may keep ants away. Destroy colonies of aphid-tending ants if necessary. See Information Package I for methods of ant control. Keep in mind that ants often are beneficial insects and eliminating them may not be the best strategy.

Many parasites have been successfully introduced for control of aphids (Clausen 1978; Olkowski et. al. 1976). Parasites often are specific for one or a few aphid species, requiring accurate identification of the aphid species in order to match the correct parasite species to the problem. Consult with federal and state extension officials

before considering implementation of a parasite release program.

Predators also have been used with good success against aphids. Specific predators have been imported from overseas to help combat a variety of aphids, including the balsam woolly aphid (Mitchell et al. 1970). Many of these have become established and have proven successful in aphid control, but not against the balsam woolly aphid. Good results have also been obtained with native predators, such as ladybird beetles, green lacewings, and syrphid flies. Ladybird beetles and green lacewings can be obtained from commercial supply houses. A list of suppliers is available (Redmond 1982).

Natural predators and parasites may be augmented by various techniques. A sugar or sugar and protein food supplement may be sprayed on plants to attract green lacewings and ladybird beetles (Hagen et. al. 1970; Schiefelbein and Chiang 1966). Larvae of predators and aphid mummies may be collected in one area and released in the control area. The adults of predators such as syrphid flies and parasitic wasps may be encouraged to stay in an area by planting nectar producing flowering plants to provide food for the adults. Carroll and Hoyt (1984) report good control of apple aphids in orchards by using earwigs reared on dog food and released at 5 or 6 per tree. "Earwig retreats" made of cardboard and paper towels were placed in the trees and straw was scattered on the ground under the trees to encourage the earwigs to stay. Aphid densities declined to less than 50 in earwig-augmented trees compared with over 3000 in trees kept free of earwigs.

Pathogens for the control of aphids have been used successfully in greenhouses, but only with limited success in field situations. A fungal pathogen, Verticillium lacanii, is available commercially in Britain, but not yet in the United States.

In an integrated control program in several cities in California, mary of these techniques were combined with the result that pesticide usage dropped and aphid (and other pests) control improved dramatically (Olkowski 1973; Olkowski et al. 1976; Flint and van den Bosch 1981). The first step was to institute a monitoring program to accurately assess the aphid problem on trees lining city streets. Pest species were identified from the

many species of trees involved. Aesthetic thresholds were established and management techniques were applied only if the thresholds were exceeded. Parasites of exotic aphid species were located in the region of origin and imported for release. Several species of imported parasites became established and have contributed to the management program. Heavily infested trees were pruned to remove the highly susceptible inner canopy. Where aphid-tending ants interfered with predators and parasites and enhanced aphid populations, a band of a commercial sticky substance was applied around the base of the tree. In Berkeley, where the program began, pesticide usage went from hundreds of pounds per year to zero, and the aphid problem became negligible.

4. **Management Alternatives - Chemical:**

Dormant oils are used early in the year, before bud break, to kill aphid eggs on oil-tolerant plants.

Soap and water applied under high pressure are very effective against non-gall-making aphids on most plants. The high pressure stream knocks many of the aphids off the plant and the soap kills a great many of the remainder. Soap treatments may need to be repeated during the season. Insecticidal soaps, such as Safer Agro-Chem's Insecticidal Soap®, are recommended for aphid control in the NPS.

Contact your regional IPM coordinator to determine which, if any, pesticide is best-suited for your aphid management program.

5. **Summary of Management Recommendations:**

1. Begin monitoring early in the year, using the aphid monitoring form shown on page II-22. Record the presence of aphid parasites and/or predators.

2. Set threshold level based on importance of plant or its location in historical or natural areas. As a general guide, the threshold is when the aphid population is medium and fewer than 50% of the aphids show signs of parasitism or disease.

3. If aphid populations were high in the previous season, consider using a dormant oil in the spring to kill aphid eggs.

4. Control may also be necessary if sooty mold is a problem.

5. Use mechanical and cultural controls where feasible. Use aluminum foil or white plastic mulches in newly planted areas. Crush aphids with fingers if infestations are not too extensive. Use a stream of water to wash aphids off plants. Control aphid-tending ants by preventing them from reaching plants, using sticky substance around tree trunks, or bone meal or crushed charcoal barriers around gardens. Destroy ant colonies if necessary. Eliminate alternate host plants in the vicinity of more desirable plants.

6. Encourage natural predators and parasites. Import lacewings, ladybird beetles, syrphids, and aphid mummies from outside areas to control areas. Plant nectar-producing flowering plants that attract adults of these insects. Provide suitable habitat that will encourage predators to remain in the vicinity.

7. Consider release of exotic parasites in cooperation with federal and state experts.

8. Spot treat with insecticidal soap or other approved insecticides when necessary.

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V. PERSONAL COMUNICATIONS

Christopher Eagar
Biological Technician
Uplands Field Research Laboratory
Great Smoky Mountains National Park
Gatlinburg, Tennessee 37738
(615) 436-7120

Manya Stoetzel
Research Entomologist
Systematic Entomology Laboratory
USDA, ARS
Beltsville, Maryland 20705
(301) 344-3168

VI. APHID MONITORING FORM

Park: _____ Sample Unit (leaf, stem, etc.): _____

Plant or Hedge
Map Location # _____ Monitor(s): _____

Date	# aphids per sample unit	Aesthetic Measure (1-10)	Action taken & date	Predators observed (yes/no)	Parasite evidence (%)	Honeydew Sooty mold Problem (yes/no)	Aphid Population Density Index (see back) and Additional Comments

Aphid Monitoring Form - Back Page

Population Density Index - from page II-12

None	(0)	- no aphids seen;
Very Light	(V)	- one to a few aphids per plant and only a few scattered young plants infested, or one to a few aphids per leaf, shoot, or other section of larger plant or tree and only a few colonies per large plant with the colonies on the young tender leaves or buds;
Light	(L)	- 5-25 aphids per plant and many plants infested, or with many colonies on larger plants or trees, and the colonies not confined to young shoots;
Medium	(M)	- 25-100 aphids per plant and most plants infested, or with large numbers of aphids on larger plants or trees and not in recognizable colonies, but diffuse and infesting many leaves, stems, etc.;
Heavy	(H)	- more than 100 aphids per plant with virtually all plants infested, or with stems, leaves, buds, etc., solidly covered with aphids.

Notes:

NATIONAL PARK SERVICE
IPM Information Package

BATS IN STRUCTURES

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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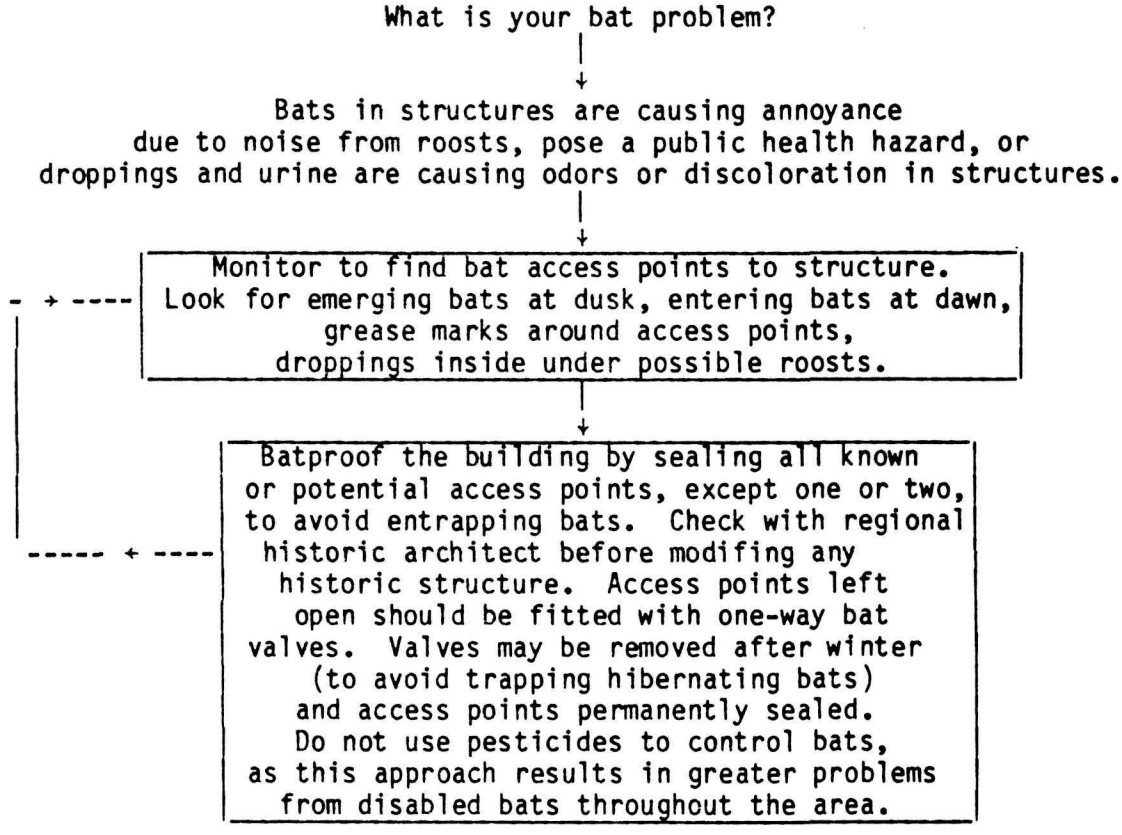
I. BAT IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. BIOLOGY AND ECOLOGY OF BATS

1. Species Described:

Bats (order Chiroptera) are the only mammals capable of true flight. Of the more than 40 species of bats in North America, 3 species commonly inhabit structures (other species such as the Eastern Pipistrelle occasionally may be found in structures in some areas of North America).

1. Little Brown Bat - Myotis lucifugus. The little brown bat weighs 1/4 - 1/3 ounce with a wingspan of about 7 inches. It has a glossy sheen on the brown back hair. Apparent differences between this species and the big brown bat are primarily in comparative size.

2. Big Brown Bat - Eptesicus fuscus. The big brown bat weighs 2/5 - 3/5 ounce with a wingspan of about 10 inches. It is pale brown (desert form) to dark brown.

3. Mexican Freetail Bat - Tadarida brasiliensis. The Mexican freetail bat is chocolate brown with short, dense fur. The tail extends well beyond the edge of the tail membrane. Wingspan is about 8 inches. Colonies give off a musty odor (Ebeling, 1975).

See Burt and Grossenheider (1964) for detailed discriptions and illustrations of North American bats.

2. Geographic Distribution:

1. Little Brown Bat - Found throughout North America from the tree line in northern Canada and Alaska to northern Arizona and New Mexico in the West, and to southern Georgia in the East.

2. Big Brown Bat - Found throughout North America from the tree line in northern Canada and Alaska to southern Georgia. Absent from most of Florida.

3. Mexican Freetail Bat - Found in southern North America from northern California to Kansas in the West, Texas and South Carolina to Florida in the East, extending north in the Appalachians to Kentucky and southern West Virginia.

See Burt and Grossenheider (1964) for detailed range maps of North American bats.

3. Habitat:

All North American bats are nocturnal, returning to roost during the day. Some species of solitary bats pass the day hanging in trees among foliage. Gregarious or communal (the terms are often used interchangeably) species roost in small groups in hollow trees, caves, mines, or structures. Roosts of several thousand to several million Mexican freetail bats have been reported in caves in the West (i.e. Carlsbad Caverns, New Mexico, and Nye Cave, Texas). The bats covered in this information package are gregarious species.

Any bat found on the ground, floor, or flying about during daylight hours should be considered abnormal and should be treated with caution because of the possibility of its being rabid.

4. Hosts:

Most bats in North America, including those discussed in this package, feed exclusively on insects which they capture on the wing. A few species feed on nectar and pollen and may be important pollinators, especially in desert areas. The three species of bat discussed in this package do not feed on nectar or pollen.

5. Life Cycles:

Most bats mate in the fall; young are born from early spring to early summer. Most species give birth to 1-2 young, but some species may have up to 4 young at a time (Burt and Grossenheider, 1964). Females give birth once a year, or once every other year. Gregarious species leave their young clinging in groups to the ceiling or walls of the roost while the females fly out to hunt at night. Solitary species take the young bats with them, clinging to their fur; young bats grasp the female with their limbs and are equipped with recurved teeth that maintain a firm hold in nipple tissue, from which they hang suspended during roosting (Constantine, 1979). In some gregarious species (e.g.; Mexican freetail bats), nursing is communal; any female provides milk to any baby. In other species, mothers seek out their own offspring. Young are able to fly and forage for themselves by late summer. Banding studies indicate that bats may live up to 25 years (Constantine, 1979).

Some species migrate to warmer areas in winter, while others go into hibernation. Most northern bats hibernate in caves or other natural structures, although some may hibernate in buildings.

1. Little brown bat - Northern populations migrate south and hibernate in caves or other suitable shelters, including buildings.

2. Big brown bat - Most bats in the northern part of the range migrate south. Some hibernate in the north. Commonly found in buildings in the winter.

3. Mexican freetail bat - Migrates to the southern portion of its range for winter. This bat is a strong flier, and banded individuals have been recovered in winter roosts over 800 miles from their breeding areas.

6. Seasonal Abundance:

Bat populations, like those of most small mammals, are at their highest in late summer (after the young are born), and before winter (when mortality rates are high).

7. Responses to Environmental Factors:

Bat populations are in decline throughout North America due to disturbances of roosting and nesting areas, habitat destruction, and the use of pesticides.

8. Impact of Bats:

8.1 Direct Impact:

Bats are beneficial to humans. They consume large quantities of mosquitoes and other insects. They may be considered pests only when they roost in structures and become annoying to humans.

8.1 Indirect Impact:

Bats, like all warm-blooded animals, are susceptible to infection by the rabies virus. Nearly all cases of rabies transmitted by bats to humans involve cases where sick and disabled bats were handled by people (Constantine, 1979). The incidence of rabies among wild bats is less than 0.5% (Constantine, 1979). Rabies has been transmitted to humans by virus contained in aerosolized droplets in the humid atmosphere of a bat cave in Texas (Constantine, 1967).

Bats in the Southwest often harbor Rio Bravo virus, which is difficult to distingush from rabies except by highly sophisticated tests. Rio Bravo virus is relatively harmless to humans.

Histoplasmosis fungi (Histoplasma capsulatum), which may cause moderate to severe lung infections,

may occur in bat dung, and may be transmitted by dust particles to humans near roosts in the humid southeastern U.S. This method of transmission is considered rare, however. H. capsulatum is more commonly found in bird droppings associated with soil.

Dermestid beetles may infest bat dung, due to its high protein content. This problem may be serious where woolens, furs, feathers, or insect specimens are stored. See IPM Package for museum pests.

Bat ectoparasites may seek hosts after bats have been excluded from structures; however these ectoparasites are highly specialized, do not attack humans, and will die for lack of hosts a few days after bats have been excluded.

9. Natural Enemies:

Bats are preyed upon by owls at night, and occasionally by other raptors, mammalian predators, and snakes during the day when roosting.

III. BAT MANAGEMEMT

1. Population Monitoring Techniques:

Bats in structures may be monitored visually. Aside from the actual sighting of bats in the structure, look for grease marks, stains, and fur around openings to the outside. Inspect all openings for grease marks and other signs; little brown bats and other small species can pass through openings as small as 3/8 inch (V. Flyger, U. Md., personal communication). Within the possible roosting area, look for urine stains and droppings localized about the roost site and departure holes. Bats often urinate and defecate before leaving the roost to lessen flight weight. Bat droppings are rather dry and crumble easily, while mouse droppings are firm and moist. Bat droppings are composed primarily of insect parts which can be readily observed. Old bat droppings may be grey, and are drier than fresh droppings.

The presence of bats can also be detected by rustlings, squeaks, and scratchings, especially in the early evening and early morning when bats leave and return to the roost. Some species of bats (e.g. palid and big brown bats) feed while hanging in night roosts. In such cases, insect parts such as wings and legs, as well as droppings may indicate the presence of bats.

2. Threshold/ Action Population Levels:

The determination of action thresholds and treatment levels will vary according to the situation and park. Many people enjoy bats and encourage their presence. Bats roosting in small numbers or in outbuildings and little-used structures should be tolerated, and in some circumstances, encouraged. Tolerance will be lower when bats are in large numbers in major structures, or when droppings cause aesthetic damage or attract insect pests.

3. Management Alternatives - Nonchemical:

Bats should be managed if at all possible by nonchemical means. The recommended method of management is exclusion by batproofing. Batproofing is the only known permanent management tool to keep bats out of structures.

Batproofing consists of closing access to a structure after the bats have left to forage at night, or after they have left for the winter.

An additional benefit to batproofing is the energy saving accrued when cracks and other openings are sealed.

All entry points should not be sealed at the same time, in order to avoid sealing bats into the structure where they will die and cause objectionable odors. Bats sealed in a structure may find their way into living quarters.

To batproof a structure, carefully observe all points from which bats emerge in the early evening, or enter just before dawn. Often, these places will be discolored by urine stains or grease marks from the bats' fur. As mentioned previously, any opening greater than 3/8 inch may be large enough to admit bats. All openings except one or two should be sealed from the outside during the day, or from the inside at night after the bats have left. Use caulk, putty, small mesh screen, glass-fiber insulation, wood, or sheet metal. Bats do not gnaw and will not reopen closed entries.

A one-way valve has been designed by D.G. Constantine. It consists of a base tube of 1/32 inch thick, 4.9 cm butyrate tubing, 24 cm long, squared off at one end and cut at 45° at the other end, and a collapsible tube of 4-Mil thick polyethylene tubing the same size as the base tube, but squared at both ends. Attach the tubes, end to end with tape. The squared-off end of the base tube can be fitted in or over ceiling holes, and the 45° end can be used at wall holes (Constantine, personal communication). Contact Constantine (see Section V) for plans and illustrations. Bat valves are not commercially available.

In some cases, the collapsible sleeve can be used alone, fitted over holes with tape.

Bats can leave structures fitted with valves by sliding down the tube, but the pliable, collapsible section prevents their ascending back up the tube.

To avoid sealing hibernating bats in the structure in winter, seal all known or potential entries but one or two, and fit those with bat valves. Valves should remain in place until the return of warm weather, when they can be removed and the holes sealed permanently.

Use the following guidelines when batproofing structures (from Constantine, 1982):

Winter - This is the best time to batproof a building if it is known with certainty that the bats are absent, whereupon all known and potential entry holes should be sealed. If some bats are suspected or known to hibernate in the building, sealing should be supplemented by the installation of 1 or more valves to assure that all bats can leave after the weather warms in the spring, after which the valve(s) should be removed and the sites sealed.

Early Spring - Batproofing can proceed from the time the weather warms until just before bats are born (bats are born as early as about 1 May in some areas). All known and potential entries should be sealed except for the installation of 1 or more valves, which can be removed and the final holes sealed after all bats have left.

1 May through 31 August - No batproofing should be attempted during this interval, when young, nonflying bats may be present. The bats should be left undisturbed.

1 September until Winter - Proceed as during winter.

Bats often find harborage under Spanish tile roofing. Manufactured plugs used to block openings in the bottom row of tiles fit poorly and may actually increase the attractiveness of the site to bats by blocking light and drafts. In small areas, stainless-steel wool (non-rusting) may be placed 6 inches from the outer opening inside the tiles to repel bats. If the building is to be reroofed to replace tarpaper under the tiles, a layer of fiberglass batting (repellant to bats) should be installed over the tarpaper and directly under the tiles. The material should not be applied within 6 inches of the open ends of the tiles in order to prevent birds from using the material for nesting.

Rain gutters can be used to block ready access by bats; bats enter tiles by swooping upward and landing on or under the ledge below the open tiles. Rain gutters installed directly under open tile ends interfere with and prevent landings. The gutter should be flush with the wall, and any openings between the gutter and wall should be covered with screening or sheet metal (Constantine, 1979).

4. Management Alternatives - Chemical:

Chemical control of bats in structures is not recommended because other bats will move into the vacant roosts.

Toxins used for bat control such as DDT (registered for special use permits), or anticoagulants such as chlorophacinone, tend to scatter sick and disabled bats over wide areas, increasing the likelyhood of human and pet contact with diseased bats.

Repellents such as Napthalene or sprays containing mustard oil provide only temporary control. Repellents, if applied when young are present, may cause the adults to abandon them. The young may die in the structure, causing odors and attracting other pests such as dermestid beetles, flies, and roaches.

Use of toxins against bats is prohibitted in 20 states (Strohm, 1982). Check with the regional IPM Coordinator before initiating any bat control program.

5. Summary of Management Recommendations:

1. Batproof structures by closing off access points by use of one-way bat valves. Batproof only during the correct season to prevent flightless young from being sealed in.

2. After bats have left a structure, permanently seal with caulk, wire mesh, wood, fiberglass insulation, or sheet metal. Make certain that bats are not sealed in the structure. If bats may be in the structure, seal all points but one. Seal the remaining hole (preferably at night) during the correct season (when all bats have left) or when you are certain that no bats remain.

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V. PERSONAL COMMUNICATIONS

Dr. Vaghn Flyger
University of Maryland
College Park, MD.

Dr. Denny G. Constantine
State of California Department of Health Services
2151 Berkeley Way,
Berkeley, Ca.
94704

NATIONAL PARK SERVICE
IPM Information Package

EXOTIC WEEDS II: TREE OF HEAVEN, JAPANESE HONEYSUCKLE, MIMOSA TREE, SIRIS TREE, SENSITIVE PLANT, GIANT SENSITIVE PLANT

Final Report

10 July 1985

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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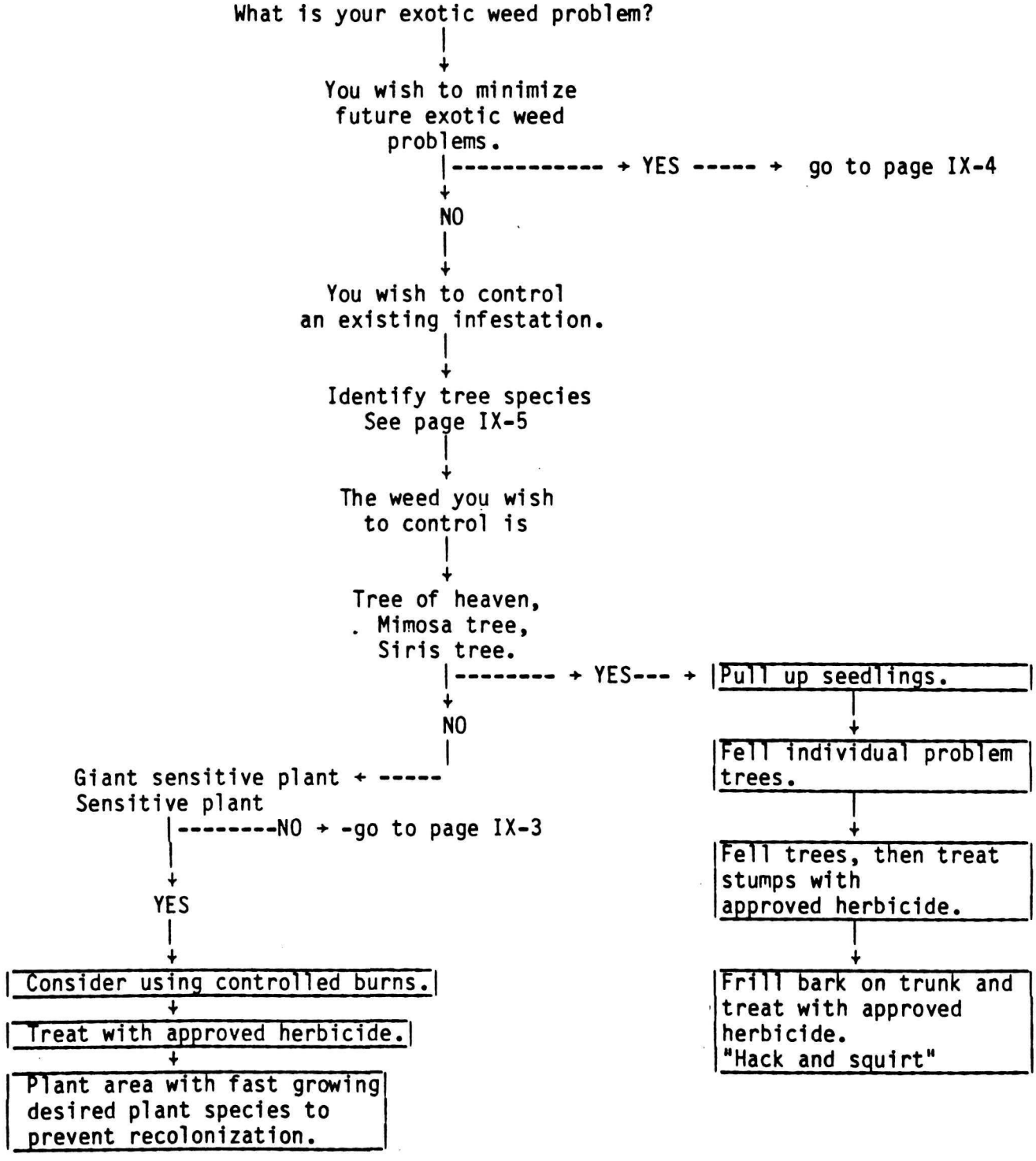
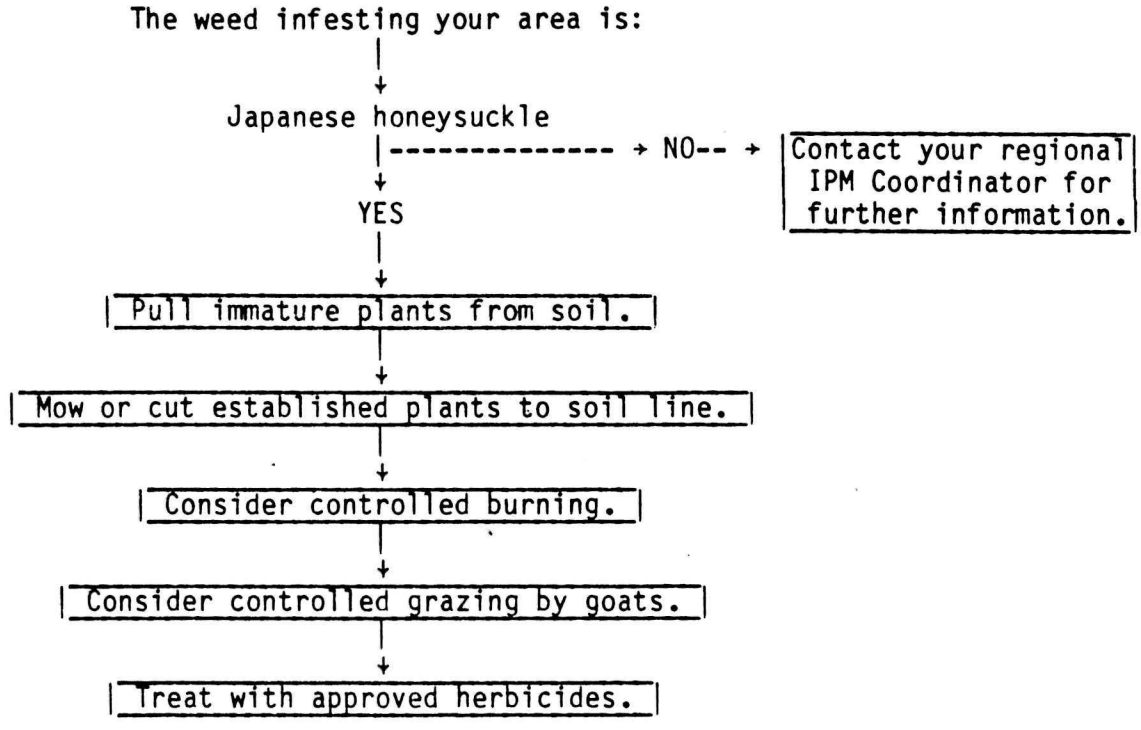
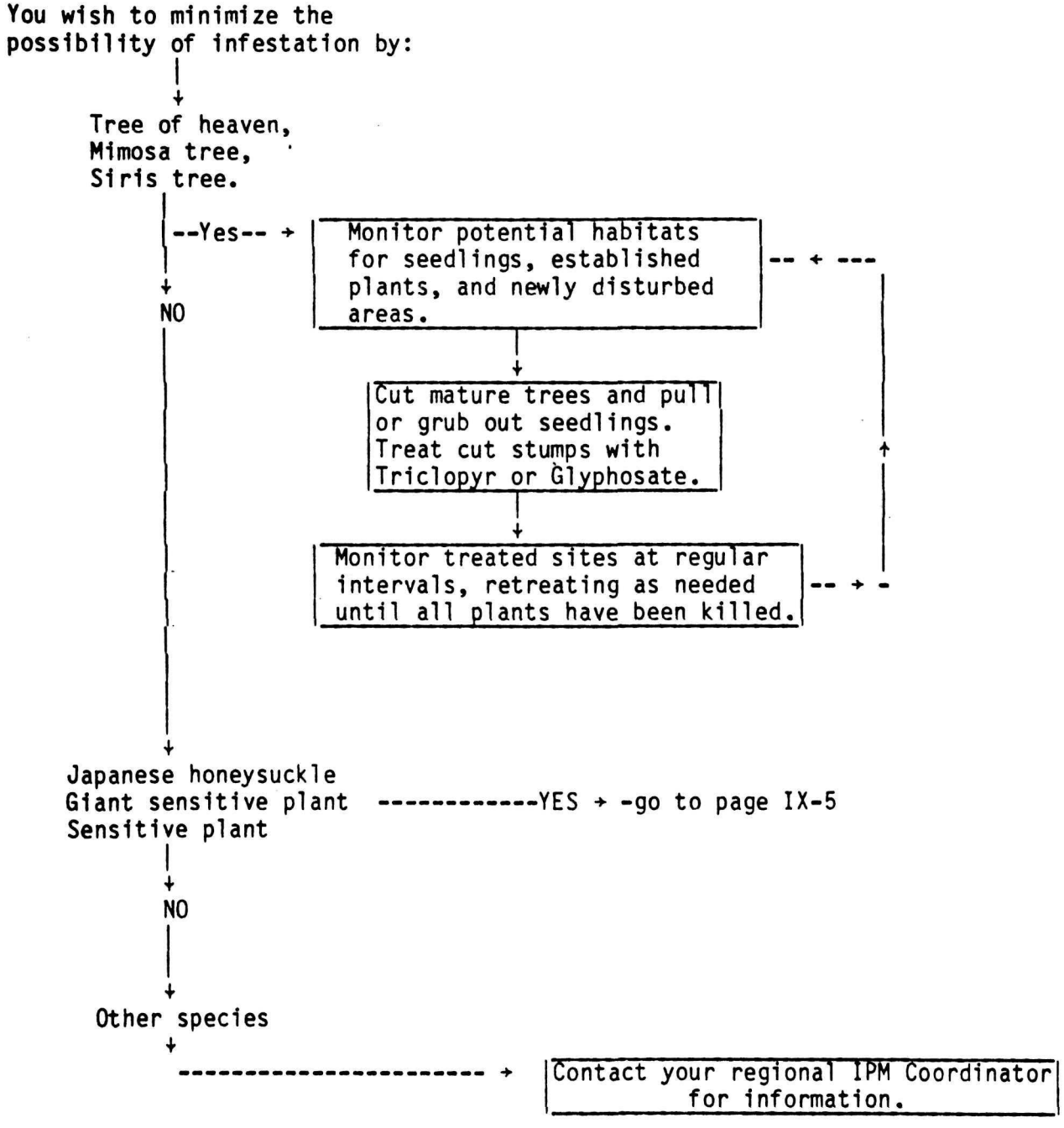
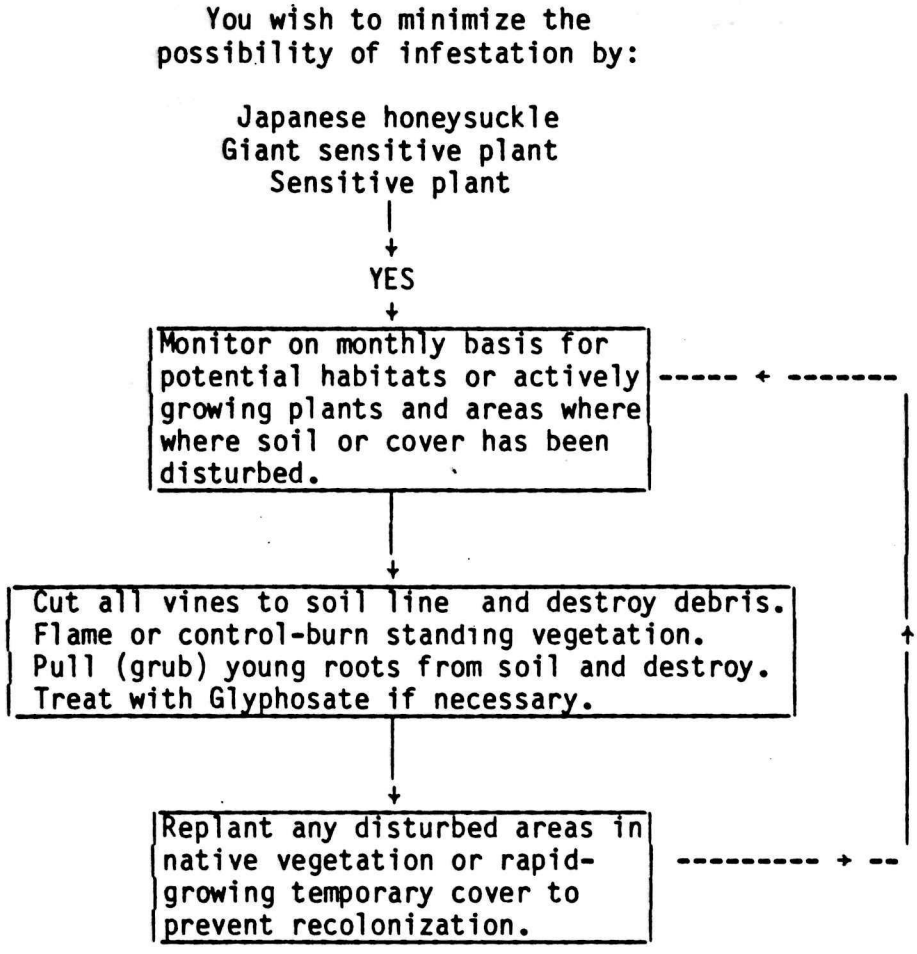
I. EXOTIC WEEDS IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




The weed infesting your area is:
Japanese honeysuckle
NO
Contact your regional IPM Coordinator for further information.
YES
Pull immature plants from soil.
Mow or cut established plants to soil line.
Consider controlled burning.
Consider controlled grazing by goats.
Treat with approved herbicides.


You wish to minimize the possibility of infestation by:
Tree of heaven,
Mimosa tree,
Siris tree.
--Yes--
Monitor potential habitats for seedlings, established plants, and newly disturbed areas.
NO
Cut mature trees and pull or grub out seedlings. Treat cut stumps with Triclopyr or Glyphosate.
Monitor treated sites at regular intervals, retreating as needed until all plants have been killed.
Japanese honeysuckle
Giant sensitive plant
Sensitive plant
YES
-go to page IX-5
NO
Other species
Contact your regional IPM Coordinator for information.


You wish to minimize the possibility of infestation by:
Japanese honeysuckle
Giant sensitive plant
Sensitive plant
YES
Monitor on monthly basis for potential habitats or actively growing plants and areas where where soil or cover has been disturbed.
Cut all vines to soil line and destroy debris.
Flame or control-burn standing vegetation.
Pull (grub) young roots from soil and destroy.
Treat with Glyphosate if necessary.
Replant any disturbed areas in native vegetation or rapid-growing temporary cover to prevent recolonization.

II. EXOTIC WEEDS BIOLOGY AND ECOLOGY

1. Species Described:

1. Tree of heaven - Ailanthus altissima (Miller) Swingle is a tree in the family Simaroubaceae. A tall (to 20 m; 60 ft), polygamous tree, it often colonizes by root sprouts. Stump sprouts (twigs) can grow 2-4 m in length in a single summer. Leaves are alternate, odd-pinnately compound. The 15-27 leaflets are lanceolate, acuminate, and entire except for 1-5 rounded basal teeth; each leaflet has a prominent dark green gland (extrafloral nectary) beneath or near the apex, and is puberulent and glandular on both surfaces; petioles are 0.2-1 cm long. Flowers are radially symmetrical, in large (often 40 cm; 12 inches long) terminal panicles. There are 5 sepals, each less than 1 mm long. There are 5 green petals, densely pubescent toward the base, 1.5-2.5 mm long; 10 stamens in staminate flowers, 2-3 stamens in perfect flowers, and none in pistillate flowers. Flowers occur from late May to early June. A large cluster of pink fruits develops from July to October.

   The flowers and vegetative parts, if bruised, are ill scented, almost nauseating on hot days.

2. Japanese honeysuckle - Lonicera japonica Thunberg. A high climbing or trailing vine in the family Caprifoliaceae, with the stems glabrous to densely pubescent. Leaves are evergreen, ovate, elliptic to oblong, 3-7.5 cm (3/4 -2 1/2 inches) long, 1.5-4.5 cm wide, acute, entire, ciliate or eciliate, with the base rounded. The leaves of new shoots in the spring are often lobed with petioles 3-10 mm long. Flowers are very fragrant, paired, subtended by 2 leafy bracts, 0.5-3 cm long, usually petiolate, the corolla is 2-lipped, white or pink, fading to yellow. Flowers occur from April to June. Fruits are berries; black, glossy, globose, 5-6 mm long. Fruits are produced from August to October.

3. Mimosa tree, Powder-puff tree, Silktree, Mimosa - Albizia julibrissin Durazzini (family Leguminoseae). A flat-topped, unarmed (thornless), deciduous tree to 12 m (35 ft) tall. Leaves are evenly bipinnate, decidous and glandular, 1-2 dm (4-6 inches) with 6-24 approximately opposite pinnae, each about 10 cm (5 inches)

long; leaflets 20-40 per pinnae, are sessile, strikingly asymmetric, 8-15 mm long, by 3-5 mm wide. Paniculate flower heads are composed of 15-25 sessile flowers, the peripheral ones are functionally staminate, while the central flowers are perfect. Flowers from May to August. Fruits are thin, ligulate, nonseptate, indehiscent, and 8-18 cm long, 2-3 cm broad. Fruits from July to November.

4. Siris tree, Woman's tongue - Albizia lebbeck (L.) Benth. (family Leguminosae). A medium-sized deciduous tree 20-40 feet high, to 1 1/2 feet in diameter or larger, with spreading crown of thin foliage. The bark is gray, smoothish, becoming fissured or rough as the tree ages. The inner bark is pink and bitter-tasting. Twigs are greenish, becoming gray or brown. Leaves are twice pinnate (bipinnate), 6-16 inches long, with 2-4 pairs of pinnae, each with 4-9 pairs of leaflets. Leaflets have very short stalks less than 1/16 inch long, the midrib is not in the center; occasionally with a second prominent vein from the base. Leaflet edges are not toothed, dull green above, light green beneath, and sometimes minutely hairy. The terminal leaflets are broadest above the middle. Flowers are borne in heads or umbels at the end of lateral stalks. Each flower is on a short slender hairy stalk 1/4 inch long. Flowers are cream-colored, fragrant, the stamens tipped with light green. Fruits are flat pods, broad, straw-colored, 4-8 inches or more in length, 1-1 1/2 inches broad, usually in large numbers. Pods remain on the tree for some time after seeds and/or leaves have fallen. The sound of the empty pods rattling in the wind gives the tree one of its common names; woman's tongue. Seeds are brown, oblong, flattened, 3/8 inch long. Sapwood is whitish, and the heartwood is light yellowish brown to light brown. See Little and Wadsworth (1964) for illustrations.

5. Giant sensitive plant - Mimosa invisa Mart. (family Leguminosae). An erect, climbing, ascending or prostrate, biennial or perennial (depending on the climate) shrub, in the legume family, which often forms dense thickets (Holm et al., 1977). This species possesses a strong root system, often becoming woody at the base. Stems, up to 2 m (6 ft) tall, are conspicuously angular throughout the length,

with many randomly scattered recurved spines or thorns 3-6 mm long. Leaves are bipinnate, 10-20 cm long, somewhat sensitive to the touch, pinnae 4-9 pairs. Leaflets 12-30 pairs, sessile, opposite, lanceolate, acute, 6-12 mm long. Flowers are pale pink, and occur in heads, 1-3 heads in the axils of leaves, on stalks 1 cm long, hairy, about 12 mm in diameter. There are twice as many stamens as petals. Fruit is a pod, spiny, 3-4 seeded, borne in clusters, linear, flat, 10-35 mm long, split into one-seeded sections. Seeds are flat, ovate, 2-2.5 mm long, light brown. See Holm et al. (1977) for illustrations.

This species may be distinguished by angular stems with recurved thorns or spines, and by the stamens which are twice the number of petals. Leaves are not very sensitive to touch. This species has been designated a noxious weed by the USDA (Westbrooks, 1981).

6. Sensitive plant - Mimosa pudica L. A much-branched perennial herb in the legume family. It is slightly woody at the base; with either an upright or low trailing habit, from 20-100 cm (8-40 inches) in height; stems stiff with thorns and scattered prickles on internodes, reddish brown or purple. Leaves normally with 1-2 compound leaflets, bipinnate; leaflets 12-25 pairs, oblong-linear, pointed, with hairy margins, 9-12 mm long, 1.5 mm wide, leaflets when touched, draw back and fold up together with pinnae and petioles. Flowers in heads, pinkish, ovoid, 9 mm in diameter, on axillary peduncles 12-25 mm long with prickles, 4 stamens. Pods attached in a cluster, oblong, almost flat, pointed at tip, edges armed with small, outstanding prickles, 1-2 cm long, 3-5 mm wide, breaking into one seeded joints; 1-5 seeds, flattened, small (3 mm in diameter). See Holm et al. (1977) for illustrations.

   This plant is easily recognized by its extreme sensitivity to touch; the leaflets fold closed and the petiole droops.

   See Holm et al. (1977), Radford et al. (1964), Fernald (1950), Little (1953), Little and Wadsworth (1964), Gleason (1963), or other field guides or flora for illustrations and detailed descriptions of species.

2. Geographic Distribution:

1. Tree of heaven - Introduced into the U.S. from Asia (China) as a host tree for the Cynthia moth (Samia cynthia [Drury]), which was introduced for silk production. Distribution in the U.S. is from Massachusetts to Iowa and Kansas, and south to southern Texas and Florida. Established to a lesser extent in the western U.S. from southern Rockies to the Pacific Coast States.

2. Japanese honeysuckle - Introduced into the U.S. from Asia. Distribution in the U.S. from the Central Atlantic states to Missouri and Kansas, south to Florida and Texas.

3. Mimosa tree - Introduced into the U.S. as an ornamental from Asia and Africa. Distribution in the U.S. from Maryland, Kentucky, and Indiana, southwards.

4. Siris tree - Escaped from cultivation in south Florida and the Florida Keys. Probably a native of tropical Asia, but widely planted throughout the tropics as a shade tree and ornamental. The range extends to Bermuda and West Indies, Central America, south to Brazil. Introduced from Egypt into southern Florida about 1900.

5. Giant sensitive plant - Originally from Brazil. This species is a weed in many tropical and subtropical countries. Found in the U.S. in Hawaii.

6. Sensitive plant - Originally from tropical America, this species is widely introduced and now has a pan-tropical distribution. Considered a troublesome weed in the Caribbean region and South America. U.S. distribution is limited to Hawaii and Puerto Rico.

3. Habitat:

1. Tree of heaven - Fence rows, roadsides, waste areas, almost everywhere except in forest shade. This species is often a nuisance since it spreads by below ground roots. It is common in dusty, smoggy areas such as inner cities where most other trees fail, and is often utilized as an ornamental there.

2. Japanese honeysuckle - Originally planted as an ornamental and to stabilize road banks, this species has invaded woodlands, fence rows, and fields, outcompeting and killing native wild flowers, shrubs, and tree seedlings.

Common to abundant at low altitudes, but spreading into uplands.

3. Mimosa tree - Introduced as an ornamental, now escaping into fields and waste areas, not yet believed established in forests, but commonly found on forest borders.

4. Siris tree - Introduced as a shade tree and ornamental, established in pastures and on hillsides in dry coastal regions. This species is highly tolerant of salt spray.

5. Giant sensitive plant - Found in moist waste places, plantations, pastures, and cultivated areas. A serious weed in sugar cane plantations. Scrambles over other vegetation with the spiny stems, forming spreading tangled masses or impenetrable thickets up to 1.5-2 m (6 ft) high.

6. Sensitive plant - Found in cultivated areas, lawns, waste places, common in settled areas. Grows on a wide variety of soils and has a high tolerance to shade. Often grown as an annual ornamental for its showy flowers. Grown as a cover crop in some tropic countries for its nitrogen-fixing abilities. A common weed in many cultivated crops and in pastures, where its high populations and thorny stems make grazing difficult.

4. Hosts: Not applicable.

5. Life Cycles:

1. Tree of heaven - Flowers in late May to early June. Fruits borne from July to October. This species propagates readily from underground sections.

2. Japanese honeysuckle - Flowers from April to June. Fruits are borne from August to October.

3. Mimosa tree - Flowers from May to August. Fruits borne from July to November.

4. Siris tree - This species propagates readily from seed. Flowers from April to September and fruits nearly throughout the year.

5. Giant sensitive plant - Reproduces by seeds enclosed in spiny pods well adapted to being dispersed by animals. Biennial or perennial, depending on site. Seedlings, only a few weeks old, may produce viable seeds, some of which may germinate immediately, others may remain in the soil for several years before germination.

6. Sensitive plant - Annual, but behaves as a perennial in warm areas. Bristled seeds are adapted for dispersal by animals or people. In tropical regions, this species flowers all year. Freshly harvested seeds may germinate within 2 weeks in moist soil. Seeds may remain in soil for several years before germination; seeds stored under laboratory conditions have shown 2% germination rates after 19 years (Holm et al., 1977).

6. Seasonal Abundance:

1. Tree of heaven - Foliage is present and growth occurs from spring to fall.

2. Japanese honeysuckle - Foliage is present year-round, but most growth occurs from spring to fall.

3. Mimosa tree - Foliage is present and growth occurs from spring to fall.

4. Siris tree - Foliage is present and growth occurs from April to September. Pods remain on tree year-round.

5. Giant sensitive plant - Foliage and flowers occur throughout the year in the tropics.

6. Sensitive plant - Grows throughout the year in the tropics. Cultivated as an annual.

7. Response to Environmental Factors:

1. Tree of heaven - Intolerant of deep shade; not found in forest environments. Tolerates conditions in cities, ie.; low moisture, compacted soils, and air pollution.

2. Japanese honeysuckle - Tolerates partial shade. Shades out and outcompetes most native plants.

3. Mimosa tree - Not established in forest environments. Often injured by severe winters.

4. Siris tree - Intolerant of cold temperatures. Grows well in pastures (full sun) and in dry conditions. Tolerant of salt spray.

5. Giant sensitive plant - Grows best in moist cultivated or waste places.

6. Sensitive plant - Grows on a wide variety of soils, in many areas. Commonly found in cultivated or waste places. Highly tolerant of shade, often grows under coconuts.

8. Impact of Exotic Weeds:

8.1 Direct Impact:

1. Tree of heaven - The major impact of this species is aesthetic; it may not be desirable in historic or cultural areas.

2. Japanese honeysuckle - This species is considered a major pest due to its ability to outcompete and shade out native vegetation.

3. Mimosa tree - See 8.1.1.

4. Siris tree - See 8.1.1. This species may outcompete native vegetation due to its ability to rapidly colonize suitable habitats.

5. Giant sensitive plant - This species overruns and outcompetes native vegetation in large areas. It further impacts native species by being unpalatable to most grazers and by having the ability to trap animals caught in thickets; animals or people may die or become seriously injured if they become ensnared in these thickets. Animals will not browse or step on stems due to the recurved thorns (Holm et al., 1977).

6. Sensitive plant - See 8.1.5. An alternate host to several species of parasitic flowering plants and of the the root-knot nematode Meloidogyne sp. which is a serious pest of many crop plants (Holm et al., 1977).

8.2 Indirect Impact:

Since these weeds are all good colonizers, their presence on ruins or other structures should be discouraged to prevent structural damage from roots. See also IPM Information Packages XIV and XV.

A second indirect impact of exotic weeds is the cost required to control them.

9. Natural Enemies:

1. Tree of heaven - The Cynthia moth (Samia cynthia) feeds on this species, but it is rare outside of urban habitats (Pyle, 1983).

2. Japanese honeysuckle - No natural enemies are reported for this species.

3. Mimosa tree - Attacked by mimosa wilt (Fusarium oxysporum perniciosum), a fungus. Also attacked by mimosa webworm (Homadaula anisocentra Meyrick), which also attacks the native honey locust tree; and by the root-knot nematode Meliodogyne incognita.

4. Siris tree - No natural enemies are reported for this species.

5. Giant sensitive plant - No natural enemies are reported for this species.

6. Sensitive plant - No natural enemies are reported for this species.

III. EXOTIC WEEDS MANAGEMENT

1. Population Monitoring Techniques:

Monitoring techniques for the introduced weed species discussed in this IPM information package consist of periodic visual inspections. All observations and treatments should be recorded (see Monitoring Form, page 19).

Care should be taken to monitor small, slowly expanding populations which have not reached pest status. A slight change in environmental conditions (i.e., hydrologic regime, fire regime, storms, etc.), could enable populations to grow rapidly (Anonymous, 1983).

2. Threshold/ Action Population Levels:

1. Tree of heaven - This species should be controlled on an individual basis whenever it is found in a non-ornamental situation, or is undesired.

2. Japanese honeysuckle - Since this species is a rapid colonizer of disturbed areas, control efforts should be triggered whenever this species is observed in areas where it is not desired, or when necessary to prevent disruption of native communities.

3. Mimosa tree - See III.2.1.

4. Siris tree - Control efforts should be triggered whenever this species is found growing in a non-ornamental situation.

5. Giant sensitive plant - Control efforts should begin whenever this species is found due to its rapid colonization ability and thorny growth.

6. Sensitive plant - See III.2.5.

3. Management Alternatives - Nonchemical:

1. Tree of heaven -

Cutting - This process involves removal of all above ground growth. Regeneration of stump sprouts and from underground parts is not prevented.

2. Japanese honeysuckle -

   A. Cutting - Vines may be chopped just above ground level. Cutting is repeated every 2 weeks to deplete nutrient reserves in the roots, and prevent resumption of photosynthesis. Cutting does not affect roots which will continue to grow until their energy and nutrient supplies are depleted.

   B. Flaming - By playing a kerosene torch over leaves on the same schedule as cutting, foliage is wilted and nutrient supplies in the roots are depleted. As with cutting, flaming will not affect roots.

   C. Burning - Although few quantitative studies occur in the literature, Barden and Matthews (1980) recommend controlled burning. Two annual burns in an experimental plot reduced honeysuckle crown volume by 80%. Ground cover was reduced by 35%. Fires killed most above-ground vines, but gound cover was maintained by resprouting roots. Burning may be combined with previous flaming which wilts and dries leaves, providing fuel for the burn.

   D. Grubbing - Consists of mechanical removal and destruction of the entire plant, including the root. If all root tissue is removed, no regrowth can occur, and repetition is not necessary. Grubbing is labor intensive and may be locally destructive. Grubbing is most effective from fruiting to winter and early spring when plant reserves are lowest.

   E. Grazing - Controlled grazing by goats may serve to reduce honeysuckle crown and ground cover densities, but as with controlled burning, resprouting roots will regenerate unless nutrient reserves are depleted by continuous grazing pressure.

   Regardless of the control method used, care must be taken to prevent reinvasion from nearby areas, or by seeds transported by birds or other wildlife. Planting the area with fast-growing native vegetation or grasses may prevent recolonization.

3. Mimosa tree -

   Cutting - See III.3.1.

4. Siris tree -

   Cutting - See III.3.1.

5. Giant sensitive plant -

   Controlled burning - See III.3.2.

6. Sensitive plant -

   Controlled burning - See III.3.2.

4. Management Alternatives - Chemical:

1. Tree of heaven - Current treatment consists of felling and stump treatment with ammonium sulfamate or Glyphosate. Chemical treatment kills remaining tissue and prevents regrowth of stump sprouts. Trees may be frilled and treated without felling.

2. Honeysuckle - Recommended herbicides for honeysuckle in a 2 year control program are applications of glyphosate (2.24 kg/ha; 2 lb/acre) in the first year, followed by applications of glyphosate (6.72 kg/ha; 6 lb/acre) the second year. Mclemore (1981) reports that an acceptable level of control (70%) was reached during a 2 year experimental control program.

3. Mimosa tree - See III.4.1. and III.4.4.

4. Siris tree - Control used by NPS (Everglades N.P.) consists of basal bark sprays of Triclopyr with carrier and dye (dye is used to prevent redundant treatments), applied to the complete circumference of the trunk 12-15 inches above the ground to runoff on ground. All major stems originating 12-15 inches off the ground should be treated (Anonymous, 1983). See also 4.1.

5. Giant sensitive plant - See III.4.6.

6. Sensitive plant - Patro and Tosh (1974) recommend postemergence application of 2,4-D as the best chemical control measure for this species.

Consult with your regional IPM Coordinator to determine which, if any, pesticide is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Tree of heaven - Felling individual problem trees and treating the stumps with approved herbicides to prevent regrowth may be sufficient for control in most situations. Depending on the growth form of the plant, basal bark treatments of Triclopyr or foliar treatments with Glyphosate may be required in some cases.

2. Japanese honeysuckle - Regular cutting (or flaming, where applicable) followed by spot treatments of herbicides or regular controlled burns combined with spot treatments or grazing pressure may control honeysuckle in most situations. Grubbing or other mechanical methods should be sufficient for small infestations.

3. Mimosa tree - See III.5.1.

4. Siris tree - See III.5.1.

5. Giant sensitive plant - Flaming, burning, and postemergence applications of 2,4-D followed by spot treatments with approved herbicides may be sufficient for control in most situations. Broadcast treatments with approved herbicides may be required to treat large infestations.

6. Sensitive plant - See III.5.5.

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V. EXOTIC WEEDS MONITORING FORM

Date:_____ Recorded by :_____

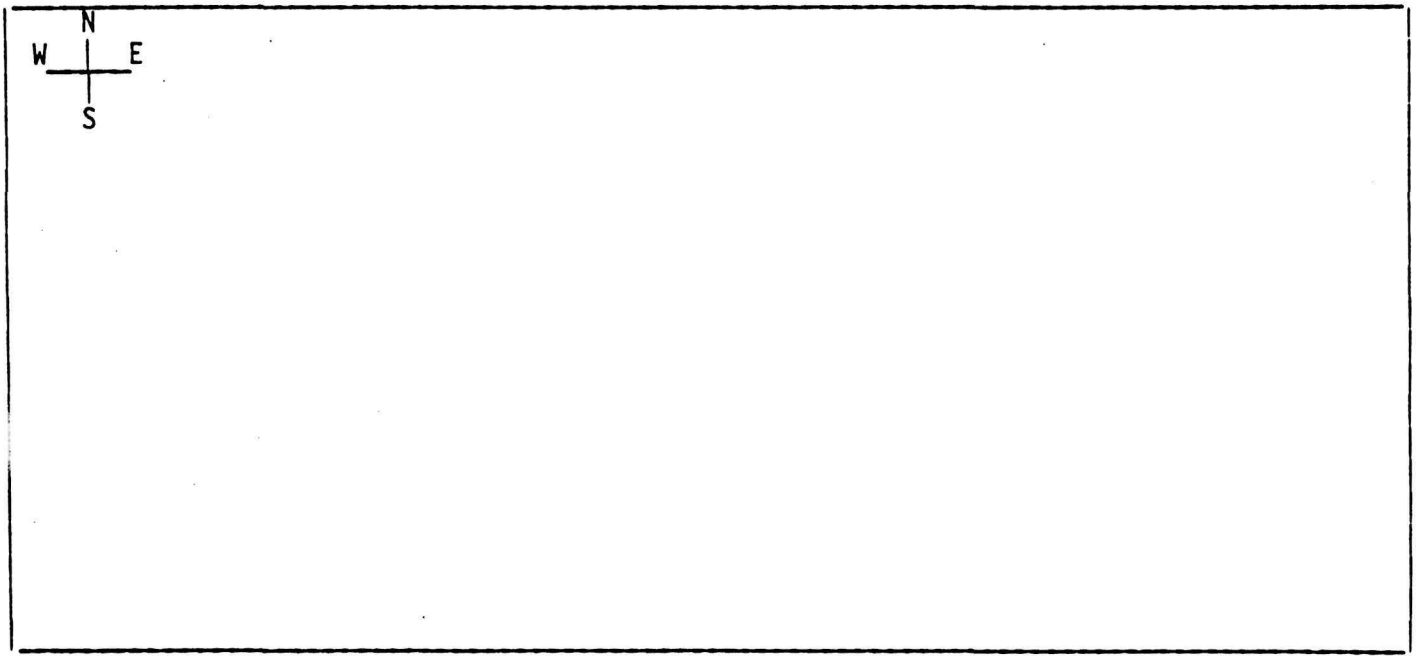
Initial survey? Y N Follow-up survey? Y N Date of initial survey_____

Weed species monitored: Location:

Treatment recommended: Size of area:

Date treatment carried out:

Map of treatment area; show plants or groups of plants treated, plants not treated, landmarks, and other prominent features (use back of sheet if required).



Notes:

NATIONAL PARK SERVICE
IPM Information Package

BLACKSPOT AND POWDERY MILDEW

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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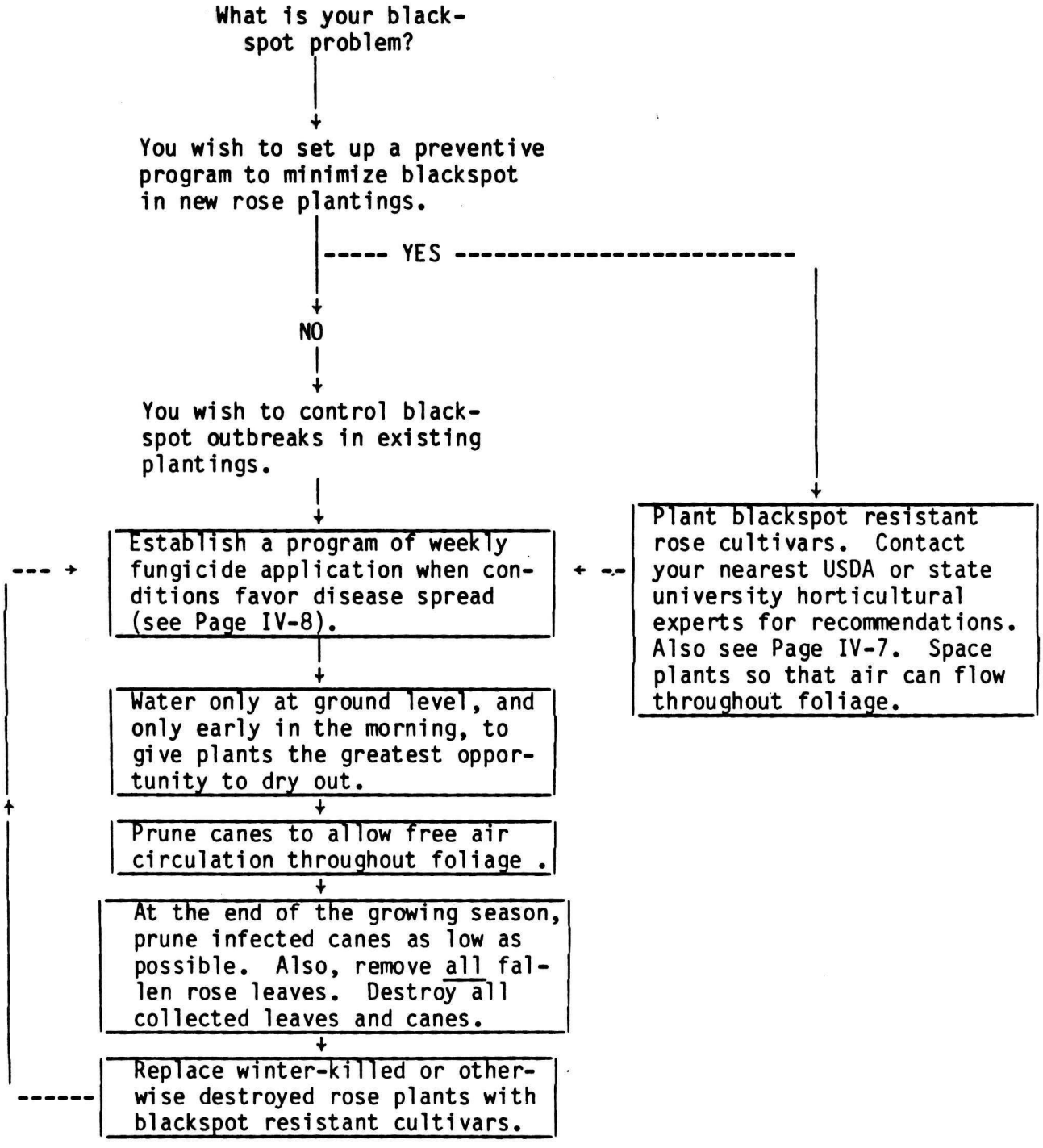
I. BLACKSPOT IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All uses of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. BLACKSPOT BIOLOGY AND ECOLOGY

1. Disease Described:

Blackspot - Caused by the fungus Diplocarpon rosae. The asexual form of the fungus, Marssonina rosae, is more commonly observed. Since the pathogen is microscopic and requires specialized equipment to grow and be observed in culture, it will not be described here. See Nelson (1975), Westcott (1960), or Horst (1983) for a complete description.

Symptoms of blackspot of roses include brown to black circular to irregular spots on canes, petioles, peduncles, fruit, flower parts, but most often on the upper surfaces of leaves. The spots may be up to 1/2" in diameter, and have feathery or fringed margins, due to the presence of fungal mycelium under the leaf surface. Small black pustules (acervuli) can be seen on the surface of each spot. White, slimy spore masses are produced at the tips of the pustules.

Leaf tissue surrounding the spots becomes yellow; the yellowing eventually spreads throughout each affected leaflet until it drops.

First-year canes of highly susceptible rose cultivars show purple-red, irregularly-shaped, raised blotches on immature wood, especially on succulent basal shoots late in the growing season. These spots become black and are dotted with pustules. Lesions are often small, and do not kill affected branches.

Petioles, peduncles, fruit, and sepals develop symptoms similar to leaf symptoms. Petals may be distorted and bear red spots with pustules.

2. Geographic Distribution:

D. rosae is native to Europe. It was first observed in the U.S. in Philadelphia, Pennsylvania, in 1831 (Nelson, 1975). Blackspot is reportedly found throughout the U.S.

3. Habitat:

Occurs throughout the temperate and tropical regions of the world, but it occurs with the greatest intensity where rainfall is heavy (e.g., the Pacific Northwest).

4. Hosts:

D. rosae attacks only species of genus Rosa. So-called black spot diseases of other plants (e.g., elm, cactus, delphinium, goldenrod, holly, raspberry) are caused by unrelated organisms.

5. Disease Cycle:

A. Overwintering - Both sexual spores (which occur rarely) and asexual spores can survive winter conditions. In addition, acervuli in fallen leaves and stem lesions can overwinter to produce new spores in the spring.

B. Distribution to Hosts - Sexual spores are produced in specialized fruiting bodies (apothecia) on fallen leaves; they are forcibly ejected into the air in the spring, and can be carried by wind to new infection sites. Asexual spores are formed in slimy masses, so must be carried to new hosts by rainsplash and/or in irrigation water (e.g., during overhead sprinkling).

C. Growth Within The Host - Under favorable conditions, spores can germinate and penetrate host cell walls within 13 hours after landing on an infection site. Mycelium grows intercellularly and under the surface cuticle, and produces absorbing organs (haustoria) within host cells; the haustoria obtain nutrients from the infected cells.

Symptom production may occur between three and sixteen days after infection. The yellowing and falling of diseased leaves is caused by the production of ethylene gas by affected leaf tissue; the observed symptoms are well-known responses of plant tissue to exposure to ethylene.

Acervuli form between the leaf epidermis and cuticle between 11 and 30 days after infection. Apothecia form only in leaves that have fallen; additional acervuli may also form then.

6. Seasonal Abundance:

Blackspot is most abundant during the late spring, early summer, late summer, and early fall. Hot summer temperatures and cold winter weather are unfavorable for fungal growth and disease development.

7. Responses to Environmental Factors:

Asexual spores must be wetted for at least 5 minutes before they can germinate, even at 100% relative humidity. Conidia must be continuously wet for at least 7 hr for infection to occur (Horst, 1983). The optimum temperature for spore germination is 64°F, and that for disease development is 75°F. No infection occurs in dry air.

8. Impact of Blackspot:

8.1 Direct Impact:	The most important effect of blackspot is defoliation of rose plants, which causes a reduction in photosynthesis. This reduces plant vigor and flower production. Heavy infections may cause deformation of flowers. Blackspot injury reduces the capacity of affected plants to store carbohydrates, increasing the susceptibility to winter kill. A severe attack in one growing season leads to poor vigor the following season in those plants that are not killed during the winter.
8.2 Indirect Impact:	Visitor dissatisfaction with heavily infested areas may occur.

9. Natural Enemies:	Few data are available concerning natural enemies of *D. rosae*. No organisms are known to exert useful levels of blackspot control.

III. BLACKSPOT MANAGEMENT

1. Population Monitoring Techniques:

The most effective technique for monitoring D. rosae populations is visual inspection of susceptible rose plants for symptoms. Inspections should be conducted regularly during the growing season. Surveys should begin when favorable spore germination conditions occur (i.e., when temperatures rise to 60°F, and when free water or high humidity [above 90%] is present).

2. Threshold/ Action Population Level:

Since even slight D. rosae attacks can cause defoliation, flower malformation, and production of new spores, tolerable levels of black spot will most likely be very low. Correlation of past disease levels (e.g., as percentages of infected leaves per plant) with plant replacement records may provide information for setting action levels.

3. Management Alternatives- Nonchemical:

A. Sanitation - All fallen rose leaves should be gathered and removed at the end of each growing season, to prevent spore release from them the following spring. At the same time, any infected canes should be pruned as extensively as possible and removed, to eliminate any spore-bearing lesions they may bear.

B. Irrigation - Free water should not be allowed to accumulate on rose leaves. Irrigation should be from the ground or by hand-held wand (at ground level). Watering should be done early in the day to prevent water from remaining on leaves and promoting spore germination. Drip irrigation, which uses less water than other methods, and which prevents contact of foliar surfaces with water, should be considered for rose plantings.

C. Ventilation - Rose plantings should not be so dense that air currents cannot circulate among branches to promote evaporation of accumulated water. Plants should be spaced and pruned to allow free air circulation within plantings.

D. Resistance - Although most roses are susceptible to D. rosae, certain cultivars are more resistant than others to the pathogen. Contact your nearest USDA Extension Service personnel or state university

horticultural experts for information on currently available resistant cultivars for your area (also see Horst 1983).

4. Management Alternatives-Chemical:

Since D. rosae spreads within host tissues, existing infections are not affected by application of most fungicides (which cannot penetrate the leaf surface). Therefore, weekly fungicide applications are required to prevent D. rosae from penetrating the host cuticle and establishing new infections. Folpet or triforine should be applied at weekly intervals when weather conditions favor spore germination (i.e., when temperatures are above 60°F, and when the relative humidity is above 90% [or free water is available for extended periods]).

5. Summary of Management Recommendations:

A. Use resistant rose cultivars wherever possible.

B. Space plants and prune stems to ensure air circulation throughout rose foliage.

C. Gather and destroy all fallen rose leaves at the end of the growing season. At the same time, cut all infected canes as close to the ground as possible, and destroy cut portions.

D. Water roses at ground level; water only during early morning, to allow wet foliage to dry.

E. Use recommended protectant fungicides to prevent or reduce disease spread. Apply once each week while conditions are favorable for fungus growth. Apply as soon after rain as possible.

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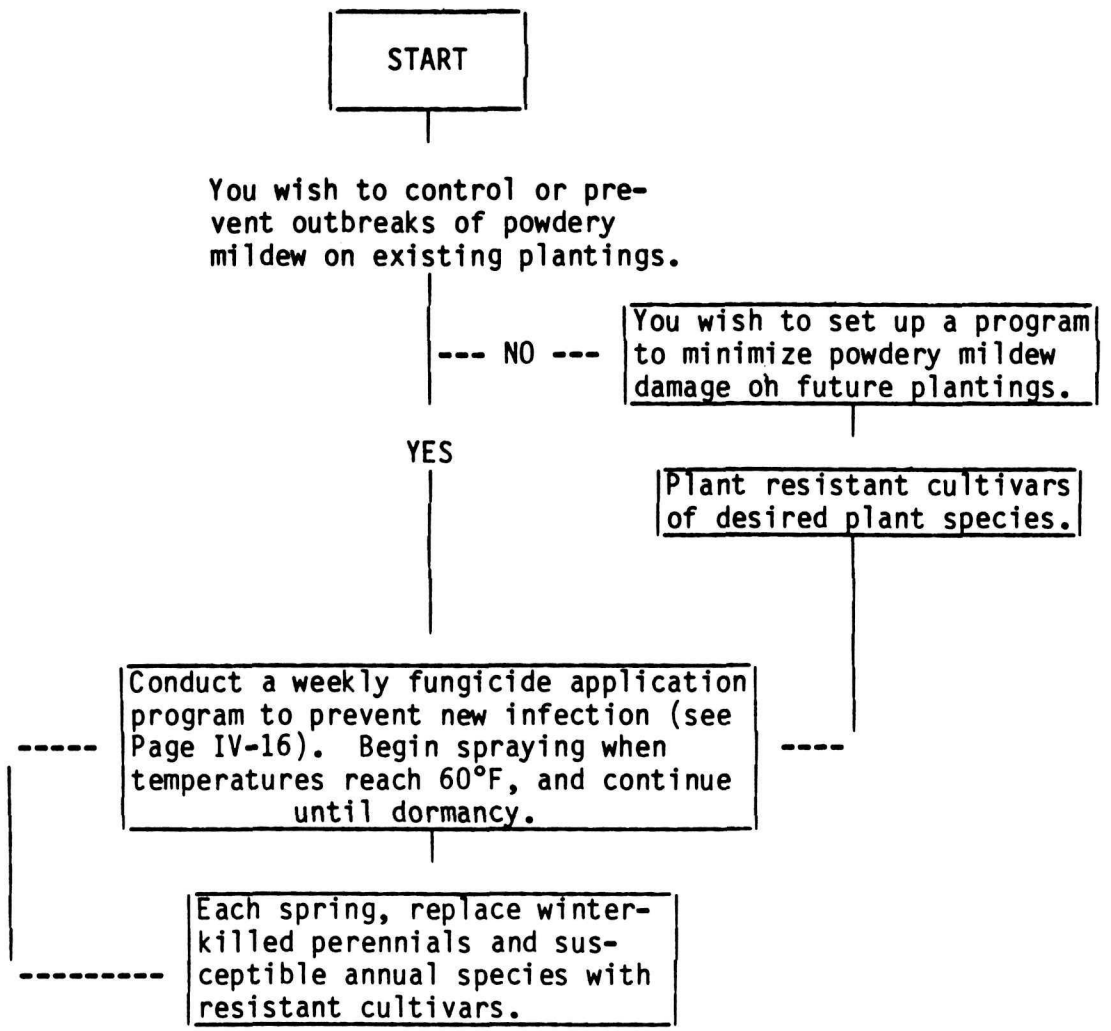
V. POWDERY MILDEW IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All uses of pesticide must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



VI. BIOLOGY AND ECOLOGY OF POWDERY MILDEWS

1. Diseases Described:

Powdery mildew diseases are caused by fungi of the family Erysiphaceae in the class Ascomycetes. The powdery mildew fungi of North America include the following:

A. *Erysiphe cichoracearum*;

B. *Erysiphe graminis*;

C. *Erysiphe polygoni*;

D. *Microsphaera alni*;

E. *Phyllactinia corylea*;

F. *Podosphaera leucotricha*;

G. *Podosphaera oxyacanthae*;

H. *Sphaerotheca macularis*;

I. *Sphaerotheca mors-uvae*;

J. *Sphaerotheca pannosa*; and

K. *Uncinula necator*.

Fungal structures are microscopic, thus they will not be described here. For detailed descriptions of these fungi, see Agrios (1978), Alexopoulos (1962), or Yarwood (1957).

Powdery mildews may be the most common and widespread of all plant diseases. They are characterized by the development of spots or patches of gray to white, powdery fungus mycelium on young plant tissues; leaves, flowers, fruit or stems may become completely covered by the powdery growth. Young plant tissues may show slightly raised, blisterlike, discolored areas. Young leaves and shoots may be curved, distorted, or deformed. Fungal growth is most common on the undersides of leaves, but under shaded conditions all surfaces will be colonized. Late in the growing season, tiny pinhead-sized sexual fruiting bodies (cleistothecia) form singly or in clusters

in older infected areas; white at first, they become yellowish, brown, and finally black as they mature.

Additional symptoms and signs of powdery mildew of rose (caused by S. pannosa) include the formation of small pink to yellow blisters on mature canes; these enlarge, turning black as the disease progresses. Infected shoots are curved, distorted and stunted. Infected flower buds fail to open fully; petals become discolored and distorted. Late-season fungal growth becomes thicker and felt-like with brown to black cleistothecia.

Additional signs and symptoms of powdery mildew of peach (caused by S. pannosa) include distortion and drying of infected flower parts, and failure of flowers to open (or open fully). Infected fruits show white circular spots which may spread over most or all of the fruit surface. The fruits become pinkish, and finally dark brown; the fruit surface becomes leathery and hard, and may be swollen or cracked.

Additional signs and symptoms of powdery mildew of grapes (caused by U. necator) include scarring and cracking of fruit. Young colonies on leaves are yellowish patches about 1/4" in diameter. Mature canes develop red, speckled, stainlike infection scars, which are visible the winter after infection.

2. Geographic Distribution: Powdery mildews are found wherever high relative humidity can occur (for even short periods) at leaf surfaces. They occur throughout North America, including Alaska, and may be most abundant in semiarid regions.

3. Habitat: Powdery mildew fungi can occur throughout the ranges of their hosts. They are obligate parasites; i.e., they can only grow while in contact with a host plant.

4. Hosts:

A. E. cichoracearum - Attacks begonia, chrysanthemum, cosmos, cucurbits, dahlia, flax, lettuce, phlox, and zinnia.

B. E. graminis - Attacks cereals and grasses.

C. *E. polygoni* - Attacks beans, soybeans, clovers, other legumes, beets, crucifers (cabbage, etc.), cucumber, cantaloupe, delphinium, and hydrangea. Over 350 host species are known.

D. *M. alni* - Attacks blueberries, catalpa, elm, liacs, linden, oak, rhododendron, and sweet pea.

E. *Phyllactinia corylea* - Attacks catalpa, elm, maple, and oak.

F. *P. leucotricha* - Attacks apple, pear, and quince.

G. *P. oxyacanthae* - Attacks apricot, cherry, peach, and plum.

H. *S. macularis* - Attacks strawberry.

I. *S. mors-uvae* - Attacks current and gooseberry.

J. *S. pannosa* - Attacks rose, peach, and apricot.

K. *U. necator* - Attacks grape, horsechestnut, and linden.

5. Disease Cycles:

Since the life cycles of the powdery mildew fungi are similar to each other, only a general life cycle is presented here.

The powdery mildew fungi overwinter as dormant branches (hyphae) in host buds, although some species (e.g., *S. pannosa* on roses) develop sexual fruiting bodies (cleistothecia) on host leaves, petals and stems late in the growing season. If the fungus overwinters as cleistothecia, then spread in the early spring is by sexual spores (ascospores) which are forcibly ejected from the cleistothecia after the fruiting bodies absorb atmospheric water, swell, and crack open. If the fungus overwinters as hyphae, spread is by single-celled, asexual spores (conidia) produced at the tips of aerial hyphae.

Spores are carried by wind to young plant tissues, and germinate if the temperature and relative humidity are proper. The first hypha produced (the germ tube) penetrates the host plant's cuticle, and enters an epidermal cell, forming a globular feeding organ (haustorium) within the still-living cell. Surface hyphae are produced, and spread across the plant surface, sending more haustoria into additional host cells.

Feeding by the fungus weakens host cells, reduces photosynthesis, and may cause uneven growth of affected tissues, leading to deformities of the affected plant organ(s).

The fungus produces specialized upright hyphae which bear chains of 5-10 conidia, giving the aerial growth its characteristic powdery appearance. The conidia are picked up by wind currents, which carry them to new infection sites on the same or other host plants.

Late in the growing season, fungal spore production slows and eventually stops, as growth conditions become less favorable. Sexual reproduction of the fungus then occurs, and round cleistothecia form within mycelial mats. Ascospores are produced within the cleistothecia in the late fall, or in some cases in the early spring of the following year. In warm areas, cleistothecia may not form at all (Yarwood, 1957).

6. Seasonal Abundance:

Powdery mildews occur from late spring to mid-fall (when temperatures are above 60°F).

7. Responses to Environmental Factors:

Spores germinate at temperatures of 60-75°F and over a wide range of relative humidities. Free water is not necessary for spore germination. Conidial formation, growth, release from conidiophores, and germination follow daily cycles (Yarwood, 1957). Cessation of conidia formation, and initiation of sexual reproduction apparently depend on the temperature reductions which occur in late summer and fall.

8. Impact of Powdery Mildews:

8.1 Direct Impact:

Infected ornamental plants may develop unsightly distorted or deformed growth. Infected flowers may be discolored, distorted, and unable to open properly. Infected fruit become unattractive and inedible. infected foliage may fall early.

8.2 Indirect Impact:

Infected plants are often weakened, and may become susceptible to injury by other pests, and to winter injury. Visitor dissatisfaction with areas showing symptoms of heavy attack may occur.

9. Natural Enemies:	Although some natural enemies of the powdery mildew fungi may occur (e.g., spore-eating arthropods), such organisms do not exert useful levels of control.

VII. POWDERY MILDEW MANAGEMENT

1. Population Monitoring Techniques:

Currently, the only available monitoring technique for powdery mildews is visual observation of plants for symptoms and signs of disease. Visual surveys should be conducted throughout the growing season, and records of all observations should be maintained. Disease severity can be noted on the basis of approximate number of infected plants, and/or percentages of infected foliage, fruit, or flowers.

2. Threshold/ Action Population Levels:

While slight infection may not be noticeable on park plantings, heavier attack may produce obvious foliar mildew, flower and fruit damage, and increased risk of susceptibility to attack by other pests. Correlation of observed levels of powdery mildew with incidence of visitor complaints or damage to plantings may provide a basis for setting action (treatment) levels.

3. Management Alternatives - Nonchemical

A. Resistance - Resistant cultivars of many powdery mildew-susceptible plant species are becoming available; contact your local USDA representatives or state university horticultural experts for recommendations for your area. Resistance is not immunity, however, and resistant plants will be attacked under favorable conditions.

B. Sanitation - Sanitation procedures such as removal and destruction of infected leaves and stems may be useful, but will not prevent reinfestation, since the fungus survives in host buds through adverse conditions. Removal of wild hosts, while theoretically useful in protecting annual plants from sources of infection left over from the previous growing season, is of little benefit due to the wide host range of some mildew species (e.g., E. polygoni), and to the ability of spores to travel over long distances in wind currents.

4. Management Alternatives - Chemical:

The only effective means to reduce powdery mildew is to prevent infection. Weekly (or more frequent, during periods of rapid plant growth, fluctuating temperatures, or frequent rains) applications of folpet or triforine will prevent new infection from taking place, provided complete coverage of foliage is achieved. Follow label directions when using these products. Contact your NPS Regional IPM Coordinator for guidance in selecting the best fungicide for your particular requirements.

5. Summary of Management Recommendations:

A. Use powdery mildew-resistant plant cultivars.

B. Treat plantings weekly with a recommended fungicide, throughout the growing season.

C. Remove and destroy infected stems and leaves.

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NATIONAL PARK SERVICE
IPM Information Package

GERMAN COCKROACH

Final Report

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Submitted To:

Dr. Michael Ruggiero
Biological Resosources Division
National Park Service
Washington, D.C.

Submitted By:

John Muir Institute
743 Wilson Street
Napa, California 20852

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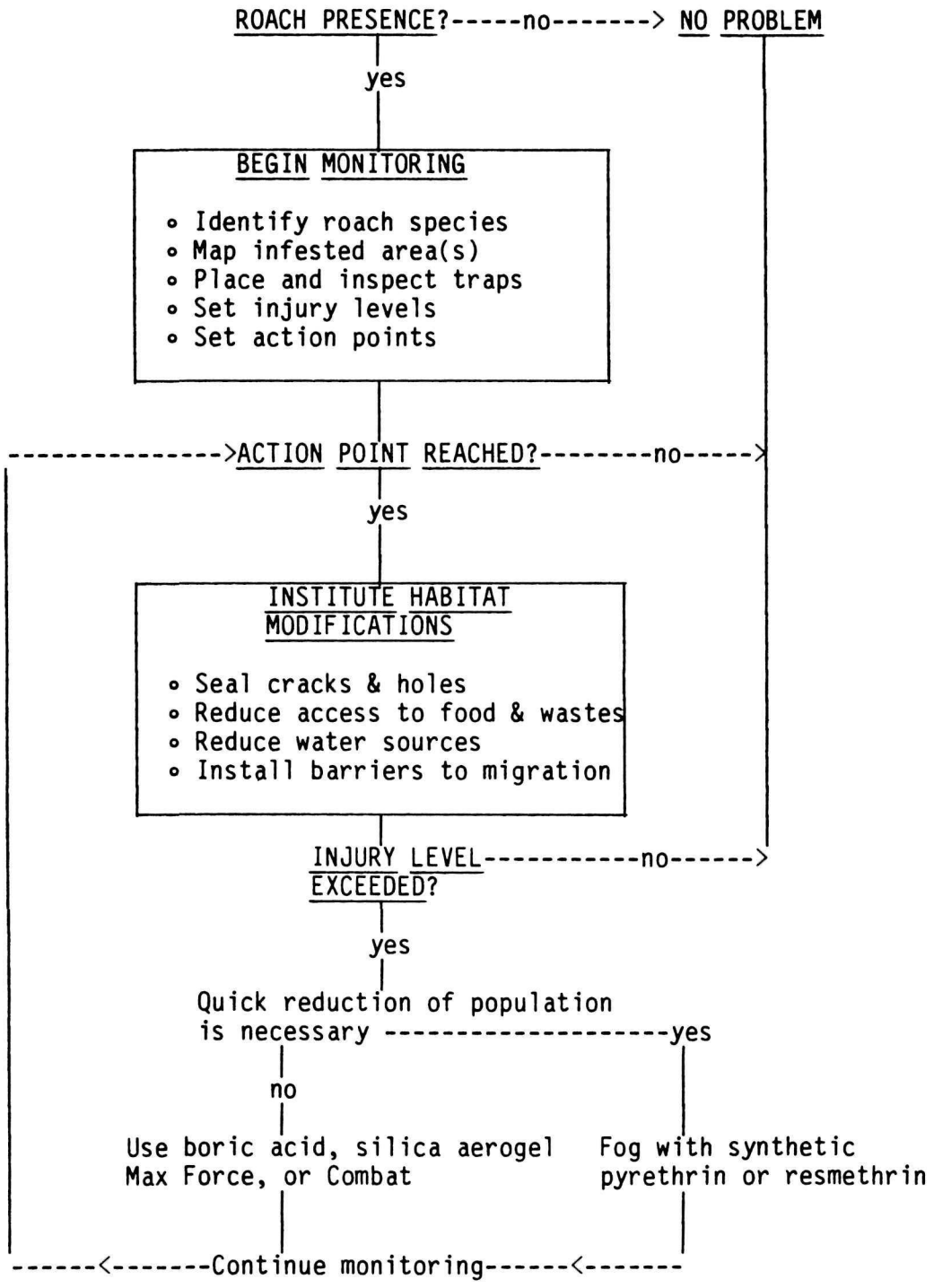
I GERMAN COCKROACH IPM DECISION TREE



II GERMAN COCKROACH BIOLOGY AND ECOLOGY

1. Species Described:

There are more than 3,500 known cockroach species in the world, 57 of them in the United States. As many as 4,000 additional species still are undescribed. Only seven cockroach species are significantly pestiferous: the German, brown-banded, oriental, smokeybrown, American, Australian, and Surinam. The German cockroach (GC), Blattella germanica (L.) is the most important domestic cockroach species in North America.

Keys to the adults and egg capsules (ootheca) of the common cockroach species have been published by the Center for Disease Control (CDC, 1976). These keys are particularly useful because they picture each cockroach species and illustrate distinguishing characteristics.

2. Habitat:

Cockroaches are found in caves, mines, animal burrows, ant and termite nests, as well as in human habitats. Their ability to hide by day in small cracks and crevices in or near human dwellings and to feed by night on water and small bits of food and waste have made cockroaches highly successful human cohabitants. Rehn (1945) considered eight domestic cockroach species including the GC as originating in Africa. Roth and Willis (1960) summarize studies on the origins of domestic cockroach species.

The GC has the widest geographical distribution of all the domestic cockroaches. Buildings provide cockroaches with microclimates similar to their native habitats in tropical East Africa. Most important to their survival is a source of moisture and warmth.

Cockroach infestations can occur in any building and often are accidently introduced as egg cases in shipped materials, groceries, used appliances, furniture, etc. However GC infestations are established by importation of adult females.

The GC is the most common cockroach on ships and planes (Guthrie and Tindall 1968). It is found in grocery stores, warehouses, office buildings, prisons and schools and prefers warm areas around furnaces and heating ducts. The GC is usually found in basements or on the first floor of buildings and is the most common species found in food preparation areas of restaurants, cafeterias and related eating establishments, and in bathrooms. A comprehensive list of typical structures found inhabited by the GC is provided by Roth and Willis (1960).

3. Life Cycle: The GC has the highest reproductive potential of all the domestic cockroach species. The life cycle of the GC starts with the egg capsule (ootheca), which is dropped by the female after she carries it for most of the incubation period. The incubation period at 76°F is 28 days, at 85°F is 23 days; and at 88°F is 16 days (but a reduced number hatch). About 35-43 nymphs emerge from the ootheca (Ross and Wright 1977) and pass through six to seven instars, and molt into adults. The pre-oviposition period is about 11 days. There are three to four generations/year (Ebeling 1978). The average development period for nymphs to adult is 103 days at 76°F, and 74 days at 85°F. Females can live over 200 days, and produce 4.4 capsules (Gould and Deay 1940).

The GC becomes most active 20-120 minutes after dark, and increases activity to a peak which ends before daybreak (Bajomi and Elek 1979). Mating, oviposition, aggregation, thigmotactic behavior, habitat preference and movements are described by Ebeling (1978). Cockroaches prefer dark narrow spaces for resting and hiding. This thigmotactic behavior has great implications for management as most human habitations have numerous cracks and crevices which can harbor cockroaches. The GC male finds its mates by contact chemo-reception via the antennae. Mate finding also is improved by the gregariousness of the species, probably enhanced by an aggregation pheromone (kairomone) present in the normal odor associated with the species. Interspecific associations between cockroach species, other species and defense against predators is described by Roth and Willis (1960).

4. Impact: Cockroaches have not been proven conclusively to be transmitters of human pathogens. However, there is a great deal of incriminating field evidence and laboratory data to indicate the potential for cockroaches to transmit a large list of disease-causing organisms. A summary of some of the more recent information is compiled in Table 1. Roth and Willis (1957) provide an excellent and exhaustive review of such information.

5. Natural Enemies: Cockroaches are attacked by microbes, vertebrates, and arthropods (Strand and Brooks 1977; Cameron 1956; and Roth and Willis 1960). Important egg parasitoids of the common domestic cockroach species are summarized in Table 2. No natural enemies of cockroaches are produced commercially and no deliberate manipulation of the natural enemies of the GC has been reported.

TABLE 1

HUMAN PATHOGENS POSSIBLY ASSOCIATED WITH COCKROACHES*

PATHOGEN	DISEASE	ASSOCIATION
Salmonella spp. & *Shigella* spp.	food poisoning	identified from roaches
Toxoplasma	toxoplasmosis	roach feces, when in contact with infected cat feces
Infectious hepatitis virus	infectious hepatitis	circumstantial evidence; lab passage through roach, probably roach feces.
Poliomyelitis virus	polio	identified from roaches
Entamoeba histolitica	amoebic dysentary	identified from roaches
Various helminths	parasites of dogs, cats, rats, poultry, etc.	intermediate vectors
Roach allergen	allergy, asthma	roach body extracts are allergenic to some persons

* Adapted from Ebeling (1977), Frishman and Alcamo (1977), Cardone and Gauthier (1979), and others.

Importation work against other cockroach species has been reviewed by Roth and Willis (1960). The egg parasites have received most attention. In an important precedent setting series of applied control projects on the University of California's Berkeley campus (Slater et al. 1979 and 1980), the Encyrtid egg parasitoid Comperia merceti has been shown to be an effective innudative agent against the brown-banded cockroach, Supella longipalpa. Other work on C. merceti is reported by Gordh (1973); Howard and Mertins (1977); Lawson (1954); Swezey (1944); and Swezey (1946).

TABLE 2.

A SUMMARY OF THE KNOWN IMPORTANT PARASITOIDS

OF DOMESTIC COCKROACHES*

COCKROACH SPECIES	NATURAL ENEMY SPECIES	STAGE ATTACKED
German	Evania punctata	ootheca
Blattella germanica	Brachygaster minutus	"
Brown-banded	Comperia merceti	ootheca
Supella longipalpa	Anastatus blattidarum	"
Oriental	E. appendigaster	ootheca
Blatta orientalis	E. punctata	"
American	Tetrastichus hagenowii	ootheca
Periplaneta americana	T. periplanetae	"
	E. appendigaster	"
	E. punctata	"
	A. tenuipes	"

* Note:

Cockroaches also can be fed upon by predatory spiders, ants, rats wasps, toads, beetles, bugs, mantids, dragonflies, geckos and scorpions.

II GERMAN COCKROACH MANAGEMENT

1. Population Monitoring Techniques:

Monitoring programs consist of an initial inspection followed by regular observations and recordkeeping. Monitoring and record keeping should show: 1) where cockroach population density is highest and, therefore, where habitat modification efforts should be concentrated, and 2) whether these efforts are actually reducing the cockroach population.

The initial inspection occurs as soon as live or dead cockroaches are seen or upon sighting other evidence of roach presence such as cast-off skins, empty egg cases or fecal droppings. At this inspection a floorplan map is made of the infested room(s) and is used to record data on roach harborage and population levels.

This data can be acquired by visual counts using a pyrethrin flushing agent or by using cockroach traps. Traps are preferred as monitoring tools as they offer an easily standardized and cost-effective method for assessing roach numbers and locations. A variety of nontoxic cockroach traps recently have become widely available throughout the U.S. (see Table 3).

Cockroaches prefer enclosed spaces and usually travel along the periphery of walls and other objects. Traps must be placed on these travel routes as cockroaches will not seek out traps if they are located outside their normal travel areas. A comparison of various cockroach population sampling systems, particularly traps, is provided in Table 2. The use of various traps in relation to the five common domestic cockroach species were compared in laboratory tests by Moore and Granovsky (1983). The results of this work are summarized in Table 4.

While traps are a logical tool for use in monitoring cockroach densities, in certain very limited situations traps also may be useful as a population reduction tool. For example, Slater et al. (1980) used sticky box traps in experimental animal rearing rooms where no insecticides were allowed. Traps may also capture occasional individuals introduced into "clean" areas with furniture, packaging, and construction changes or those cockroaches forced to move from adjacent treated areas.

TABLE 3

A COMPARISON OF VARIOUS COCKROACH POPULATION SAMPLING SYSTEMS*

SAMPLING SYSTEM	DESCRIPTION	BAIT	BIAS	STANDARDIZATION
Visual	thorough inspection with a flashlight	none	high	low
Flush	use of pyrethrin aerosol & counts	none	high	low
Jar Trap	128-ml baby food jar greased on upper inner surface	2-3 gms each of white bread & beer	against nymphs**	ok
Mr. Sticky®	commercial trap, cardboard with adhesive & bait	Chrysalis powder 83%, preservative 17%	more males most precise ***	ok
New Mr. Sticky®	same as above but new bait	ground wheat, sugar, citric acid artificial flavor and color	more males	ok
Roach Motel®	similar to above but different bait	burned molasses	more males	ok
UC Riverside	1 qt Mason jar w/5 ml Attaclay	1 slice white bread	least biased¶	ok

* Based on Owens and Bennett, 1983.

** This trap is the only one tested from which the trapped roaches can be released. It is unbiased in catching adults of either sex but catches more adults than nymphs in test populations.

*** Precision is based on the highest mean/standard deviation from repeated samples of known populations in mock test kitchens.

¶ Most accurate and representative; samples the smallest populations and introduces the least bias into a sampling program.

TABLE 4

A COMPARISON OF STICKY TRAPS IN CAPTURING
FIVE DOMESTIC COCKROACH SPECIES*

COMMERCIAL TRAPS	DESCRIPTION	RANK ORDER OF EFFECTIVENESS** (1=highest; 4= lowest) Cockroach Species				
		GC	O	A	SB	BB
Raid Roach Traps®	Bait attractant. Size & shape same as D-Con®. Brown wood grain exterior, black interior. Sticky inside.	1	1	1	1	2***
Holiday Roach Coach®	Bait packet placed in trap by user. Trapezoidal in cross section, 22x9.5-4.5 x3 cm. Outside, brown wood grain; inside, gray with sticky layer on bottom.	2	1	2	2	1
D-Con®	Molasses bait inside in center of 3 sticky bands. Rectangular in cross section. 12.5x7.2x4.5 cm with 2 cm wide internally directed flaps at both ends. Black outside, white inside.	1	1	3	3	2
Mr. Sticky®	No bait. Triangular in cross section. 18x9x5 cm. Outside yellow, blue, and orange; inside gray with sticky layer on bottom.	2	2	3	4	3

* Based on work performed by Moore and Granovsky (1983).

** GC=German, O=Oriental, A=American, SB=Smokey brown, and BB=brown-banded. Based on trap catches of 100 roaches with a relatively even age distribution placed in large screened boxes for a two week period. Most cockroaches were caught on the first day.

*** There was no statistical difference between Holiday Roach Coach and Raid but Holiday Roach Coach caught more cockroaches during the first day and over the 14 day test period.

Timing and frequency of trap placement is a function of the following variables:

a. size of cockroach populations present in particular areas
b. size, complexity and sensitivity of location(s) infested
c. amounts of competing attractants
d. resources available to monitor and manage the problem
e. skills and knowledge of the person(s) responsible for monitoring

In general, traps should be set out and inspected at least once per week where GC populations are high. Where populations are low or not evident, monthly placement and checking of traps is recommended.

Traps should be "read" the day after placement. Moore and Granovsky (1983) report that during a two-week trap exposure period under laboratory conditions simulating kitchens, the highest per day trap catches were obtained after the first 24 hours.

Monitoring programs should use floorplan maps of specific rooms or other areas in structures to indicate trap placement and catches in relation to existing features such as stoves, refrigerators, air conditioners, food storage and dispensing machines, heating ducts, etc. In addition, these maps also can be used to indicate food and water sources, and areas which are recommended for treatments. Copies of the maps can be used to communicate about structural changes and other treatment actions needed and to record habitat modifications made over time. Useful lists and line drawings (maps) of typical roach harborages such as restrooms, offices, coffee shops, food service areas, housekeeping units, locker rooms, laundries, restaurants, etc. are presented in Frishman and Schwartz (1980).

2. Action/Threshhold Population Levels:

The injury level occurs when the pest population has reached a size large enough to cause intolerable aesthetic, structural or medical damage to the resource. Unfortunately, there is virtually no literature to guide pest control personnel in objectively assessing the type, amount or degree of injury from cockroach presence. The severity of the particular

problem may be determined by placing any particular situation in one of the following categories of injury (listed in ascending order of severity):

a. aesthetic discomfort from sightings of live roaches or their products
b. unpleasant odor or taste of contaminated food
c. allergin production
d. pathogen transmission

Thereafter resources to manage the problem can be allocated by the severity of the problem as determined by assessment of population size.

The action point is that point in time when action needs to be taken to prevent the pest population from reaching or exceeding the injury level. This point is based on the size of the pest population. Trapping is a method of assessing population sizes prior to the development of injurious pest numbers. For example, Kardatzke et al. (1981), working on an Army base used 2.5 cockroaches/night as the action level for treatments. By using this approach, treatments were reduced and equal or better quality of pest control was achieved compared to the previous "preventive" system in which insecticides were applied on a routine, calendar basis. Using an "action point" approach also can reduce overall costs of the management program.

There is no absolute cockroach population level which will indicate an unacceptable degree of injury in all circumstances. Consequently there is no absolute action point for use in all situations. Rather, an action point needs to be defined for each site and situation.

3. Management Alternatives-Non-Chemical: Indirect supression strategies and tactics are those that change the conditions that create or define the pest problem.

Design refers to the design of structures and/or the design of pest control programs which minimize the development of pestiferous cockroach populations. Structural design criteria and codes exist for termites but not for cockroaches. The only published design criteria relevant to cockroach prevention were proposed by Lancaster (1977), and focus on food service carts and walk-in refrigerators.

The design of programs for suppression of cockroach populations has received a great deal of attention while the concept of cockroach prevention largely has been ignored.

The most common "preventative" approach is to treat for cockroaches on a regular schedule, whether or not cockroach presence is documented. This method places an insecticide in the environment when cockroaches may not be present. NPS pest control contract specifications should be designed to stipulate that treatments are warranted only when trap catches are at the "action point" determined by the monitoring program.

Designing structures to reduce cockroach presence would be more cost effective than efforts to suppress recurring populations. However, no studies on this approach could be located in the literature.

Habitat modification refers to those alterations to the environment which are permanent and consequently attack cockroach infestations by reducing their life supports. Willis and Lewis (1957) show female GC can survive only 13 days without food and water (these studies were conducted at warm temperatures, 81°F and in relatively low humidities, ca. 40%). With water but no food, survival was about 42 days. With both food and water females survive about 80 days. The survival time with food alone does not differ significantly from a water-only diet (i.e. 42 days). Survival also increases significantly if the relative humidity is higher (6 females survived 28 days at 70% RH with no food or water). This work indicates that priority should be placed on habitat management practices which reduce drinking water and humidity.

Drinking water for cockroaches is available in sink traps and drain pipes, wash basins, tubs, toilet bowls, in flush tanks, from condensation on cold pipes and windows, around leaking pipes and faucets, as spillage, in various water-filled containers such as pet dishes, aquaria, vases, empty beverage bottles, drainage pans beneath refrigerators, potted plants, and in various foods (Roth and Willis, 1960). Although much can be done to reduce such water sources directly through repairs and barriers, many are virtually impossible to effectively reduce or eliminate. Consequently, habitat and food reduction strategies in the vicinity of such water sources should get extra attention.

Cockroaches are thigmotactic, i.e. they prefer to have their bodies in touch with a substrate. They favor sites such as cracks where both the upper and lower surfaces of their body are touching some part of the microenvironment. Such sites are commonly found inside buildings with poorly finished construction details or in deteriorating structures. The adult GC can hide in

cracks as small as 0.06 inch wide. First instar larvae can squeeze through a gap as small as 0.04 inches (Guthrie and Tindall 1968). To reduce the carrying capacity of the microenvironment such harborage should be caulked or sealed whenever possible.

When cockroach harborages are found, accessible areas can be washed, or vacuumed and washed to eliminate egg cases, fecal material, and bits of food waste that may have accumulated. Infested materials also can be steam-cleaned. Dispose of vacuumings by placing in tightly closed containers.

Methods to eliminate habitat include plugging all small cracks around baseboards, wall shelves or cupboards, pipes, sinks, and bathtub fixtures. This can be achieved with putty or caulk (paint may also be used alone or in conjunction with either of these). Large caulking jobs are best done before repainting.

Three general types of caulk are available: 1) cartridge caulk (which requires a caulking gun) is useful for big jobs such as along floor boards or behind cabinets; 2) squeeze tube caulk is good for sealing around water faucets, vents, etc.; 3) ropelike caulk is most useful for quick temporary seals. Large holes or cracks will require special cements or other sub-stances which match existing materials.

Latex caulk is water soluble before drying but cracks after drying. Butyl caulk stays flexible, but is very sticky and requires special solvents to remove. Silicon seal is flexible, easy to apply and comes in clear and colored forms and claims to be effective for 50 years. However, it is more expensive than the other types. Although new urethane foams in aerosol cans are available, they are difficult to use with small jobs because the cans become sealed after one use and cannot easily be reopened. However, urethane is excellent for large openings (>3inches) which cannot be sealed in other ways. This caulk is available in small single-use cans which might be used up completely in a single job.

In older dwellings with many cracks, crevices, and hard-to-reach places, start by caulking where highest population levels are located. Every foot of hiding place

plugged up reduces the number of cockroaches a structure can support for as long as the plug lasts.

Reduce outdoor cockroach populations by moving debris, firewood and garbage away from the house. Prevent access to indoor spaces with screens. Commonly available aluminum window screen is adequate to repair holes in existing screens, or fill holes with Silicone Seal®. Compost or bury pet manure, or use a commerical pet waste disposal system. Use garbage cans with tightly fitting lids held on by a spring mechanism to prevent wind and dogs or other animals from scattering the contents.

Other procedures which are effective include: use of weatherstrip on cracks and crevices through which pests can enter the structure; replacement of broken windows and screens, and realigning doors or altering the door frames. Air vents, particularly those in kitchens near the stove, should be screened to prevent easy entrance. Vending machines, refrigerators and similar devices which give off heat also should be inspected for access points and the possible installation of barriers.

Food should be stored in containers that close tightly and can resist cockroach entry by chewing. Paper and cardboard boxes should not be considered cockroach-proof. Glass containers with rubber seal rings and various plastic containers that seal by pressure are good for storing packaged goods after purchase and transport. Employees who snack at their desks should be encouraged to place their food for temporary storage in cockroach-proof containers such as plastic snap-top boxes.

Special efforts to improve food and waste storage should be made where restaurants or food stands are located within office or recreational building complexes. Large kitchens need to employ food storage systems that exclude cockroaches. Similar attention should be given to the storage of food waste from which cockroaches also can obtain food. In concessions, trays of dishes and utensils containing food residues should not be left overnight for washing by the morning shift. In large office buildings the frequency of garbage pickup can be increased during the most troublesome periods, or if cockroach problems remain chronic. Since food residues remaining in garbage containers can provide sources of food for cockroaches, garbage containers should be cleaned regularly at the end of the working day.

This is useful even where plastic liners are changed regularly since food wastes can lodge between the receptacle and the liner.

There are many maintenance activities such as garbage storage and removal, food storage and preparation, cleaning, painting, and building repair which can directly affect cockroach populations. In order to reduce cockroach populations, ongoing maintenance procedures must be examined and specifically revised to incorporate cockroach suppression activities. In addition, duties involving alteration of cockroach habitat, food and water sources must be stated explicitly in maintenance contracts.

Staff should be made aware of cockroach biology and life histories and their role in encouraging cockroaches in offices, snack areas, etc., through inadequate management of wastes and storage of food stuffs.

Vacuuming and steam cleaning to kill egg cases, using a fly swatter or wet sponge to kill adults, and jar trapping are examples of physical controls used for direct suppression of cockroaches. Except where used to catch cockroaches invading into otherwise uninfested premises (e.g. on second hand furniture or equipment), these physical controls are comparatively less important within cockroach management programs.

There are no biological controls available for the GC at present. See Section I 5 Natural Enemies for further information.

4. Management Alternatives-Chemical:

Large cockroach populations, especially those which are only recently discovered, may require insecticide use in addition to habitat modification. Operator safety, cost effectiveness, pest resistance and environmental fate (mobility) are the major factors to consider in selecting an insecticide. These factors are compared for the common insecticides used against cockroaches in Table 5. Repellency also is compared since cockroaches are repelled by insecticides they can detect. Cockroaches are least repelled by boric acid (BA) and have not developed resistance to BA in well over 10 years of use.

Although boric acid can be diluted and applied as a wash, it is more effective as a light dust. Cockroaches walk through the dust and ingest the material while cleaning themselves. Thereafter, BA operates slowly, killing in 7 to 14 days. BA applied as a dust does not vaporize.

TABLE 5.

A COMPARISON OF EFFICACY, RESISTANCE, TOXICITY, AND FATE OF COMMON INSECTICIDES USED AGAINST COCKROACHES*

INSECTICIDE	EFFICACY	RESISTANCE	TOXICITY (LD_{50})	MOBILITY	COMMENTS
Acephate	H	ND	M	M	probably repellent
Boric Acid	H	0	L	L	non-repellent
Borax	M	0	L	L	non-repellent
Carbaryl	R	+	M	M	
Chlorpyrifos	R	+	M	M	
Diazinon**	R	+	M	M	
Dichlorvos	R	+	H	H	
Fenthion	R	ND	M	M	
Malathion	R	+	L	M	
Propoxur	R	+	H	H	high volatility
Pyrethrins	R	+	L	H	
Resmethrin	R	ND	L	H	
Ronnel	ND	+	L	ND	

* Insecticides taken from Schwartz (1982) and other sources. ** Ecapsulated.
KEY:
Efficacy:
H= High; M= Medium; L= Low; R= Repellent.
ND= no data
Resistance:
0= none; += resistance known; ND= no data.
Toxicity:
H= LD_{50}'s of 1-99 mg/kg; M= 100-1000; L=>1000. Based on LD_{50} data from Wiswesser (1976).
Mobility:
Same key as for Toxicity, ND= no data
Boric acid is judged to have low mobility since it does not vaporize. Those materials that are highly volatile or with a short residual life are scored with an H.

In structures, BA dust should be used where habitat modification is difficult -- around stoves, refrigerators, ductwork, in wall voids or in particularly difficult-to-seal-cracks. This material also can be blown into wall voids.

Moore (1972) evaluated the effectiveness of boric acid-silica dusts for the control of GR when buildings were treated during construction. He found BA plus 0.1% Dri-die® to be the most effective of four materials tested. After 18 months following a single treatment, only two cockroaches were flushed (using pyrethrin sprays as a monitoring tool). Untreated apartments averaged 31 cockroaches. The other materials tested included: BA alone, Dri-die® alone, and BA plus 0.1% Cab-O-Sil® (the latter is an anti-caking compound).

Cockroaches die for up to 10 days after ingesting BA. Other insecticides provide quick, short term, one-to-four day kill of some cockroaches. This short term effect can confuse the lay person into choosing such a material rather than the slower but more effective BA.

Judging by the LD_{50}, BA is one of least toxic materials available for control of cockroaches. However, BA can be absorbed through skin lesions or respired. Wear a dust mask as application methods may accidentally throw boric acid dust into the air. Keep boric acid away from food, children, and pets. Label and seal storage containers carefully.

Make needed permanent changes in the habitat and maintenance practices first; then use an insecticide if these changes alone are insufficient to solve the problem.

Additional instructions and photographs on use of a modified fire extinguisher and hand dusters to apply BA in wall voids, electrically heated food carts and other areas normally found infested with the GC is found in Moore (1973). BA also can be used in treating electrical appliances (Bajomi and Elek 1979, and Moore, 1972). Ebeling (1978) provides additional details about the use of BA.

A new product, marketed as Maxforce or Combat has also proven effective for German cockroach control (F.E. Wood pers comm). This product is formulated as a bait and is contained in sealed containers that are attractive to cockroaches.

It may be used in areas where pesticide dust or sprays are not desirable.

In extremely high infestations, where immediate knockdown of cockroach populations is need, fogging with a synthetic pyrethroid (pyrethrin or resmethrin) may be used.

All pesticides are labelled for specific uses by the U. S. Environmental Protection Agency. All label instructions must be strictly followed.

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NATIONAL PARK SERVICE
IPM Information Package

CRICKETS AND GRASSHOPPERS

Final Report

1 December 1984

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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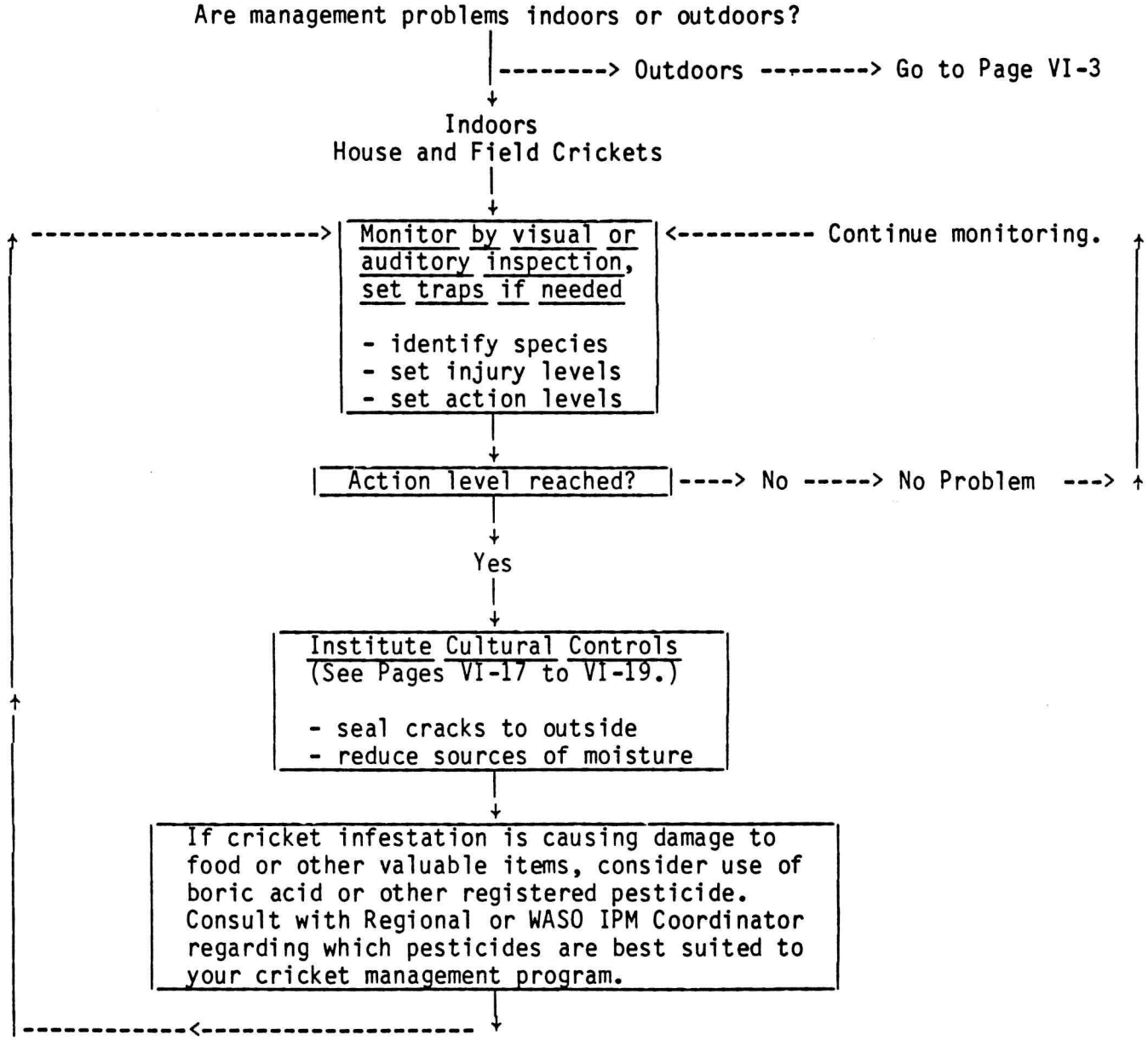
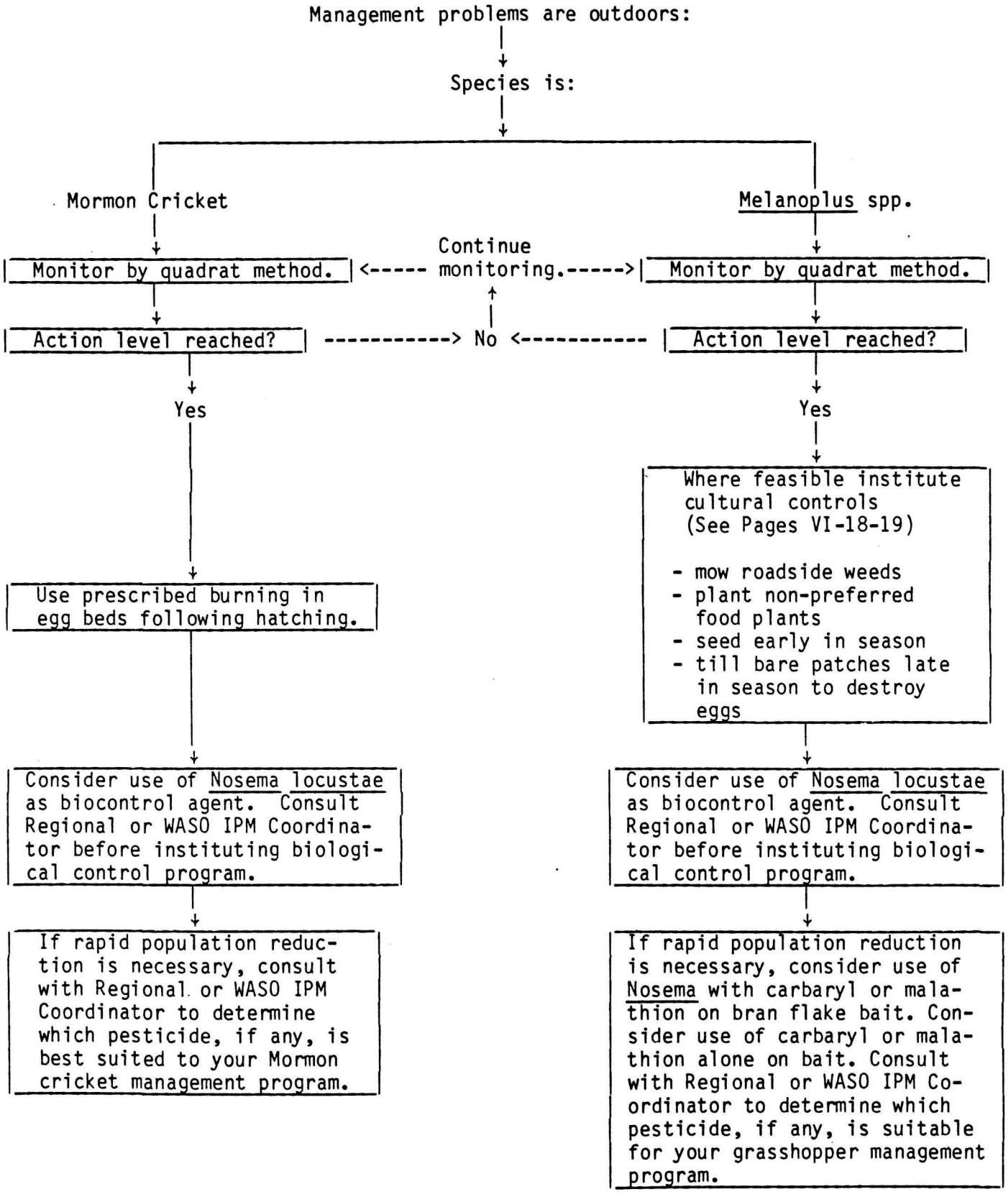
I. CRICKET AND GRASSHOPPER IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




Management problems are outdoors:
Species is:
Mormon Cricket
Melanoplus spp.
Monitor by quadrat method.
Continue monitoring.
Monitor by quadrat method.
Action level reached?
No
Action level reached?
Yes
Yes
Use prescribed burning in egg beds following hatching.
Where feasible institute cultural controls (See Pages VI-18-19)
- mow roadside weeds
- plant non-preferred food plants
- seed early in season
- till bare patches late in season to destroy eggs
Consider use of Nosema locustae as biocontrol agent. Consult Regional or WASO IPM Coordinator before instituting biological control program.
Consider use of Nosema locustae as biocontrol agent. Consult Regional or WASO IPM Coordinator before instituting biological control program.
If rapid population reduction is necessary, consult with Regional or WASO IPM Coordinator to determine which pesticide, if any, is best suited to your Mormon cricket management program.
If rapid population reduction is necessary, consider use of Nosema with carbaryl or malathion on bran flake bait. Consider use of carbaryl or malathion alone on bait. Consult with Regional or WASO IPM Coordinator to determine which pesticide, if any, is suitable for your grasshopper management program.

II. CRICKET AND GRASSHOPPER BIOLOGY AND ECOLOGY

Crickets and grasshoppers, members of the order Orthoptera, are common and widespread jumping insects. Many hundreds of species of crickets and grasshoppers occur in the United States. Although normally considered to be important components of natural ecosystems, a few species occasionally become serious pests, both indoors and in the field. Under certain environmental conditions huge swarms consisting of millions or even billions of individuals may appear, causing widespread destruction of crops and rangeland. This package describes the life histories and management of four groups that have been found to be of greatest concern in the National Park System.

1. Species Described:

A. House and Field Crickets - Members of the family Gryllidae, these are the common and widely distributed crickets with which most people are familiar. They have long slender antennae. The wings are well developed and lie flat over the back, but are bent down sharply at the sides. Male crickets chirp or sing by rubbing their front wings together. Females possess a long, straight, slender, cylindrical ovipositor, or egg-laying tube at the end of the abdomen. Both males and females have a pair of long cerci or filaments projecting from the end of the abdomen.

1. House Cricket - Acheta domesticus (L.) has a body about 5/8 - 7/8 inch long, and is light brownish yellow with dark markings on the head and thorax. The hind wings extend beyond the cerci at rest.

2. Field Crickets - Gryllus spp. - These are the large black field crickets with which most people are familiar. The males chirp both day and night. Gryllus spp. range from 5/8 - 1 inch long, and from solid black to pale straw color, with reddish or brownish coloration in the wings and legs of some species. The hind wings do not extend beyond the cerci at rest.

   The species known for many years as the black field cricket, Gryllus assimilis (Fabricius), has been shown to be a complex of five closely similar species that are separated most reliably on the basis of the calling songs of the males (Alexander 1957, 1962). Gryllus assimilis is now known as the Jamaican field cricket and the common name black field cricket is no longer used (Alexander 1957; Alexander and Walker 1962). Four other genera also are sometimes called field crickets (Alexander and Walker 1962).

Keys to southeastern species of Gryllus based on morphology are provided by Dakin and Hays (1970) and Nickle and Walker (1974).

B. Mormon Cricket - Anabrus simplex Haldeman is a shield-backed grasshopper of the family Tettigoniidae. Adults are large (1 - 2 3/8 inches) and dark shining brown to bluish black. These insects are flightless with the wings reduced to short stubs. The antennae are slender and as long as the body. The pronotum, or first segment of the thorax behind the head, is extended backwards as a shield that covers the rest of the thorax to the base of the abdomen. Males chirp by rubbing their stubby wings together. Female Mormon crickets have a flattened, upcurved ovipositor nearly as long as the body extending from the end of the abdomen. Two additional species, A. cerciata Caudell and A. longipes Caudell, are also referred to as Mormon crickets in some older literature. See Milne and Milne (1980) for photograph and further description.

C. Melanoplus spp. - This is a very large genus of the family Acrididae, or short-horned grasshoppers, that contains some of our most destructive species of range and crop land in North America. The damage is caused mainly by four species: the migratory grasshopper M. sanguinipes (Fabricius), the differential grasshopper M. differentialis (Thomas), the twostriped grasshopper M. bivittatus (Say), and the redlegged grasshopper M. femurrubrum (De Geer); another 8-10 species are also of economic importance. All of them can be recognized by their antennae which are much shorter than the length of the body, the short spine between the front legs, and the clear, colorless hind wings. They range in size from 3/4 to 1 1/2 inches long, and the females are larger than the males. They are yellowish to olive green or reddish-brown, with light stripes and/or dark red, brown, or black markings on the thorax, wings, legs, and abdomen. Males sing by rubbing their hind legs against the front wings. See Milne and Milne (1980) or Anonymous (1969) for illustrations and descriptions of several species.

2. Geographic Distribution:

A. House and Field Crickets -

1. House Cricket - This species was introduced to North America during the eighteenth century, and now is widely distributed in Canada and the United States.

2. Field Crickets - Gryllus spp. are widespread throughout North America, Central America, and northern South America. Gryllus assimilis, which is found only southern Florida in the U.S., might have been introduced there from the West Indies or a Central or South American Caribbean country where it also occurs (Alexander and Walker 1962). D. A. Nickle (personal communication) considers all species of Gryllus in the U.S. to be native. Some species in other genera have been introduced (Alexander and Walker 1962).

B. Mormon Cricket - Common from the Coast Range east to the northern and central Great Plains, and extending from Canada to Arizona. It also has been reported from Tennessee (Goodwin and Powders 1970).

C. Melanoplus spp. - Species of this genus occur throughout North America.

3. Habitat:

A. House and Field Crickets -

1. House Cricket - House crickets may be common in garbage dumps. Seeking warmth, they often enter houses as fall approaches. They are more frequently found indoors, where they may become established if food and moisture are available.

2. Field Crickets - These normally are found in open fields and along roadsides where they live in cracks in the soil and under litter. Different species have different habitat preferences. Like the house cricket, they may enter buildings in the fall seeking warmth, but do not become established there.

B. Mormon Cricket - This species occupies a wide variety of habitats, including sagebrush communities, mountain and desert shrub communities, and riparian communities (J.L. Kennedy, in litt.).

C. Melanoplus spp. - Most species are found in open grasslands, meadows, and cultivated fields.

4. Hosts:

A. House and Field Crickets - These crickets feed on juicy fruits and vegetables, flowers and developing seeds, and leaves, stems and roots of plants such as alfalfa and small grains. In houses, they may feed on wool, linen, fur, silk, nylon, rubber, and

leather, as well as meat or meat products and dead insects. They also will eat paper or other items stained with grease or perspiration.

B. Mormon Cricket - Wakeland (1959) stated that Mormon crickets are omnivorous feeders, and that they eat almost any green vegetation. They are known to feed on more than 250 species of range plants and all cultivated crops they come in contact with (Wakeland and Parker 1952). However, Ueckert and Hansen (1970) report that forbs comprise 50% of the diet of Mormon cricket adults and late instar nymphs, while grasses, clubmoss, and grasslike plants (Carex and Juncus spp.) comprise 6%, 5%, and 2%, respectively. In addition, aphids and other small arthropods form 21% of the diet, and fungi 16%. Injured or dead Mormon crickets are readily eaten by healthy individuals (Wakeland 1959; J.L. Kennedy, in litt.).

C. Melanoplus spp. - Most species show a distinct preference for particular food plants, but, in general, the economically important species tend to be omnivorous or to prefer grasses over forbs (Hewitt and Onsager 1983). During outbreaks, however, they "...frequently consume every bit of green vegetation." (Comstock 1925).

5. Life Cycles:

A. House and Field Crickets -

1. House Cricket - The life cycle takes one year to complete in the field, but populations in houses may be active year round. Mated females deposit eggs singly in cracks and crevices in dark recesses. The number of eggs laid by a female varies directly with the temperature. Eggs hatch in 8-12 weeks. The nymphal stage lasts 30-33 weeks, with 9-11 molts. After mating, females wait up to 10 days before starting to lay eggs. Oviposition may continue for 5 weeks and females may live a further 19 days after egg-laying is finished.

2. Field Crickets - The life cycles of Gryllus spp. vary from species to species and with locality. Species in northern states normally have one generation per year, but field crickets in southern states may have as many as three. Mated females deposit eggs singly in the ground by inserting the ovipositor to a depth of 1/4 - 1 inch, preferrably in sandy

soil. Many eggs may be deposited in the same vicinity, with a total of 150-400 eggs laid by each female. Eggs are elongate-oval, slightly curved, and up to 1/8 inch long. They are light honey-yellow at first, turning cream colored as they develop. Egg-laying in species having one generation per year begins in August and continues into the fall. The eggs overwinter, but most adults and nymphs die as winter approaches. Hatching depends on the weather, but generally starts in April or May. In species having multiple generations per year, nymphs and adults may be active throughout the year. Nymphs pass through 8-10 instars before becoming adults: males normally pass through 8 instars, and females pass through 9. Complete nymphal development requires 80-90 days, with the males maturing before the females.

B. Mormon Cricket - There is one generation per year in most localities, but, at least at high elevations in the Big Horn Mountains, eggs may not hatch in the first year and thus the life cycle may require 2 years to complete (Cowan and Shipman 1940). Eggs are deposited singly in the soil just below the surface, but many eggs may be deposited in one place without the female completely withdrawing her ovipositor (Wakeland 1959). Deep, well-drained soils are preferred for egg-laying (J.L. Kennedy, in litt.). Each female deposits about 150 eggs. Egg-laying occurs in the summer and development begins soon afterward. Eggs are dark brown at first, becoming dull gray as the embryos mature. Hatching does not occur until the ground warms in the following spring. Hatching has been recorded as early as mid-January and as late as August 1, but normally extends from mid-April through May (J.L. Kennedy, in litt.). First instar nymphs range up to 1/4 inch in length. They are light tan initially, becoming black with white markings on the pronotum. Nymphs pass through 7 instars over a period of approximately 60 days. As they grow they may assume various colors, showing shades of green, red, and yellow.

C. Melanoplus spp. - Grasshoppers typically have a single generation per year, but some species, such as the migratory grasshopper, may have two or three generations per year in the southern parts of their ranges. Those having a single generation per year lay eggs in the fall by depositing them in clusters

in the soil. The eggs are elongate oval, about 1/8 inch long, and are cream-colored. A glue-like secretion holds the eggs together and also binds soil particles to the eggs, producing a small case called an egg pod. The number of eggs per pod varies depending on the species: pods of the migratory grasshopper contain 15-25 eggs, those of the redlegged 25-30, and pods of the differential and twostriped 50-150. Each female lays as many as 800 eggs, depositing them in 5-40 pods. The eggs overwinter and hatch the following spring, usually beginning in late April in the southern states and in late May in the northern states. Hatching takes place over a period of several weeks. Nymphs pass through 5 instars, each instar lasting 7-10 days. Adults become sexually mature in 10 to 14 days after the last molt. Egg-laying occurs approximately 2 weeks after mating. Adults may live another 4-6 weeks after reproducing.

6. Seasonal Abundance:

A. House and Field Crickets -

1. House Cricket - Once established indoors, house crickets may be seen throughout the year.

2. Field Crickets - Gryllus spp. populations in the north decrease gradually from a peak following the spring hatching of eggs, but their presence becomes more noticeable as nymphs become larger later in the season and as adults appear and males begin calling. In populations having more than one generation per year, densities are greatest in late summer and fall.

B. Mormon Crickets - Populations are greatest in the spring immediately after egg hatch; however, the larger nymphs and adults increase steadily in numbers through spring and summer, reaching peaks from June through August.

C. Melanoplus spp. - Densities of larger grasshopper individuals increase steadily throughout the year from egg hatch in the spring to peak adult population density in August and September.

7. Responses to Environmental Factors:

A. House and Field Crickets -

1. House Cricket - These crickets are nocturnal and are attracted to lights and warmth. During the day they hide in dark cracks and crevices,

or under litter out of the light. Growth and development are faster at higher temperatures. Ghouri and McFarlane (1958) report an average of 728 eggs laid at 82°F and 1060 at 89°F. The rate of chirping is directly related to the ambient temperature. Highly favorable conditions in successive years may give rise to exceptionally large populations that eventually reach outbreak proportions. When this occurs, huge swarms of crickets begin migrating away from their breeding grounds toward new sources of food.

2. Field Crickets - As with house crickets, field crickets are nocturnal and are attracted to lights at night (Hutchins and Langston 1953; Howell and Hensley 1955). Field crickets grow faster and require fewer molts to mature at higher temperatures than at lower temperatures. The rate of chirping is directly related to ambient temperature. Outbreaks of field crickets usually occur after a rainfall which ends a period of drought (Hutchins and Langston 1953).

B. Mormon Crickets - Temperature affects hatching, growth, and vigor. In cold weather these insects seek protection in soil cracks, under rocks or in debris. Migration of nymphs during outbreaks takes place on days that are clear or partly cloudy, with air temperatures between 65-90°F, soil temperatures between 75-125°F, and winds less than about 20-25 mph.

Crickets roost in brush at night, beginning at dusk when the temperature drops below about 65°F. They leave their roosts in the morning between 7:30 and 8:00 a.m. when the temperature rises and begin feeding. About 10:30 to 11:00 a.m. the crickets begin migrating and during migration very little feeding takes place, unless a good quality food source is encountered (i.e., a bran bait). About 3:30 to 4:00 p.m. the crickets stop migrating and begin to feed, and continue to feed until dusk (BLM report quoted by J.L. Kennedy, in litt.).

C. Melanoplus spp. - Temperature affects grasshopper growth and life history in every stage of development. Timing of egg hatching depends on accumulated degree-days since laying, as do the rates of development of the nymphal instars (Gage et al. 1976). Outbreaks occur after several successive years of highly favorable conditions in which the weather is warm and not too wet in the growing

season, and high quality food is abundant. The number of grasshoppers doubles from year to year at first, then triples or quadruples, resulting in outbreaks every 8-10 years (Pfadt 1978; J. Onsager, personal communication).

8. Impact of Crickets and Grasshoppers:

8.1 Direct Impact:

A. House and Field Crickets -

1. House Cricket - These crickets may cause damage by feeding on household items, such as silk, wool, or other fabrics, food left exposed, or paper, leather, rubber, or other goods.

2. Field Crickets - Indoors, field crickets have much the same impact as the house cricket. Outdoors, field crickets may damage garden plants or field crops by feeding on flowers and developing seeds. They frequently cut off the seeds of grain crops and let them fall to the ground uneaten. The entire plant may be destroyed in a heavy infestation, with leaves, stems, fruits, roots, or tubers eaten.

B. Mormon Crickets - Injury is caused by feeding on leaves and reproductive tissues of plants, reducing yield and reproductive potential. Preferred food plants may be completely devoured even under normal circumstances, and in an outbreak young plants of many species may be completely devoured, older plants defoliated, and the twigs of bushes and shrubs may be girdled (Wakeland 1959).

C. Melanoplus spp. - See 8.1.B. Even in non-outbreak years, grasshoppers destroy in excess of 20% of all available range vegetation (Hewitt and Onsager 1983).

8.2 Indirect Impact:

A. House and Field Crickets - These insects primarily are nuisance pests indoors. The incessant chirping of the males at night is particularly annoying to some people. In an outbreak, huge swarms may be attracted to window lights, street lamps, or other outdoor lighting. Streets may become slippery with crushed crickets. Food may be contaminated by crickets walking over or defecating on it. During outbreaks, cats may feed exclusively on crickets and become emaciated and subject to fits (Ebeling 1975). In many places in the Southeast, crickets are reared

for fish bait to be sold locally or shipped to bait stores in other parts of the country. This also serves to distribute species outside their normal geographic range (Alexander and Walker 1962).

B. Mormon Cricket - Swarms of Mormon crickets crossing highways may make driving hazardous as roads become slippery with crushed crickets. Crickets may contaminate water supplies when they fall into wells or other water systems and decompose. Overgrazing may lead to increased erosion by wind and water.

Mormon cricket feeding may or may not result in competition with livestock for forage, depending on local circumstances. Cowan and Shipman (1947) concluded that such competition may occur with serious results in Nevada. However, in the vicinity of Dinosaur National Monument, heavy utilization of death camas may actually have a desirable impact on livestock growers (J.L. Kennedy, in litt.).

C. Melanoplus spp. - Overgrazing may lead to increased erosion. Grasshoppers can transmit plant diseases such as potato spindle tuber, turnip yellow mosaic, tobacco mosaic, and tobacco ringspot, and some species are vectors of parasites of birds such as poultry tapeworm.

9. Natural Enemies:

A. House and Field Crickets -

1. House Cricket - Predators include spiders, ground beetles, the American cockroach, and the conenose bug Rasahus thoracius Stal.

2. Field Crickets - Many organisms parasitize field crickets, including species of wasps, flies, nematodes, gordian worms, mites, and protozoans. Of these, Severin (1926) found that the parasitic wasp Ceratoteleia marlatti Ashmead destroys 20-50% of field cricket eggs each year in South Dakota, and the protozoan Gregarina (sp.?) reduces the vitality of infected crickets, shortens their life span, and limits production of females. Field crickets have been shown to be susceptible to infection by Nosema locustae Canning, a microsporidian (Henry and Oma 1981). Predators include: several species of spiders; a digger wasp, Chlorion cyaneum Dahlborn; and several species of birds. Spiders and birds were found to have significant impact on nymph and adult population densities (Severin 1926). Ebeling (1975)

reports that during outbreaks cats may feed on crickets to the exclusion of all other food.

B. Mormon Cricket - Mormon crickets have many parasites and predators. Parasites include wasps, gordian worms, nematodes, and Nosema locustae, an extremely promising biological control agent. Predators include sphecid wasps, ground beetles, robber flies, spiders, many species of rodents and birds, as well as, coyotes, skunks, and badgers. Groups of kestrels can be used as an aid in locating bands (J.L. Kennedy, in litt.). Wakeland (1959), who was unaware of N. locustae, concluded that while these parasites and predators serve to keep Mormon cricket populations in check under normal conditions, in outbreaks they serve little practical use. Historically, however, gulls are credited with stemming an outbreak that threatened the survival of pioneers in the vicinity of Salt Lake City in 1848.

C. Melanoplus spp. - Grasshoppers have many natural enemies. Eggs are parasitized by wasps of the genus Scelio, while flesh flies, tachinid flies, and tangleveined flies parasitize nymphs and adults. When humidity is high a fungal pathogen, Entomophthora grylli, can cause extensive epizootics. An extremely promising biocontrol agent is Nosema locustae Cannings, a microsporidian parasite fatal to grasshoppers and Mormon crickets.

Predators include many species of spiders, robber flies, predatory wasps, larvae of bee flies, blister beetles, and ground beetles. Rodents and other mammals feed on the eggs, nymphs, and adults, and birds may eat a large number of grasshopper nymphs and adults.

Although these organisms help to keep populations in check under normal conditions, and may even help end an outbreak, only the microsporidian and fungal parasites are considered to have much immediate potential for biological control.

III. CRICKET AND GRASSHOPPER MANAGEMENT

1. Population Monitoring Techniques:

A. House and Field Crickets -

1. House Cricket - The presence of house crickets usually is first noticed by hearing the males singing at night. Thus, a monitoring program consists initially of locating singing crickets. Because of the nocturnal habits of crickets, this may be done most effectively by turning on the lights in a darkened room where crickets have been heard singing, or by searching in the dark with a flashlight. If the crickets can not be located in this manner, it will be necessary to move boxes or furniture, or look behind appliances. Because house crickets seek shelter in cracks and crevices behind baseboards, in loose fitting masonry, or in cabinets, and prefer warm areas near stoves, fireplaces, and furnaces it is most productive to search these areas first. Look for signs of cricket feeding damage in fabrics, food, or other items. Holes made by crickets can be distinguished from feeding damage caused by case-making or webbing-making moths or beetle larvae because the holes are large and there is never any silk associated with the damaged areas. A floor plan map of the infested room(s) may be needed to record data on cricket harborages and population levels.

   Relative population size can be estimated by determining the number of crickets heard singing, or by visual counts. Females are attracted to singing males: therefore, for each singing male there may be assumed to be at least 2 and probably more females present (Ebeling 1975).

   Alternatively, a simple pit-fall trap may be made from a 1-quart or larger wide-mouth jar. A piece of juicy fruit or other suitable food (see Section II.4.A, Page VI-6) is put in the bottom of the jar, and the trap is positioned upright in a corner or near a known or suspected cricket harborage. It may be necessary to apply a thin film of petroleum jelly around the inner neck of the jar to prevent the crickets from escaping. Pieces of wood, cardboard, or other material are attached to serve as ramps allowing the crickets to enter. The location

of each trap is recorded on the appropriate room floor plan. Each trap is inspected and the number of crickets captured is recorded daily, and the trap emptied.

2. Field Crickets - These insects rarely, if ever, become established indoors, and are usually found close to their point of entry into a building. Auditory and visual monitoring as described for the house cricket are adequate in most situations. In cellars or infrequently used structures traps may be used if necessary. If crickets are entering a building, monitor the exterior by both auditory and visual methods. Crickets may be located during the day by disturbing their hiding places in grass or bushes, in wood piles, or under leaves or other items providing a dark protected hiding place on or near the ground. Pit-fall traps as described above for the house cricket survey may be buried in the ground up to the top of the jar, or provided with ramps for access as described above. The traps should be covered with a board or other material, leaving space for the crickets to crawl under. Traps should be inspected, the number of crickets recorded and the traps emptied daily.

B. Mormon Crickets - No completely satisfactory method is available to sample Mormon cricket populations. APHIS recommends the same quadrat method that is used for grasshoppers (see 1.C). NPS personnel in Dinosaur National Monument (J.L. Kennedy, in litt.) use circular hoops of 1 yd^2 or 0.1 yd^2 depending on the size and number of crickets to estimate population density. Twenty or more samples are averaged for each band. This technique is useful except at very low densities, in which case populations are recorded as 0-1/yd^2. Plot the location of all samples on a map and record the density, date, time of day, temperature, and the type, density and height of vegetation on a survey form, such as the one on Page 25. Record the location and extent of egg beds. These may be located by observing oviposition, and confirmed by taking soil samples and carefully sifting for eggs.

C. Melanoplus spp. - Grasshopper populations are monitored using a quadrat technique. A monitor walks in a straight line and counts the number of grasshoppers leaving a square foot of area (or 0.33 m^2 area) selected by the monitor well ahead of his

approach. Eighteen counts are made 15-20 paces apart along the line of march. The total number from all 18 square foot (or 0.33 m^2) samples is computed and divided by two to determine the density per square yard (or meter) (Anonymous 1969; Anonymous 1981). Data are recorded on a survey form such as the one on Page 25. Also record the date, time of day, temperature, and the type, density, and height of vegetation present, and the economically important species encountered. Take notes on the relative proportions of different nymphal stages and adults, mating and oviposition activity, and presence of predators and parasites. Reliable maps are used to plot the location of each area surveyed, and the density of grasshoppers at each location recorded.

The timing of a survey will depend upon the management needs of a particular Park, and the history of grasshopper problems in the area. A survey of adult populations in August or September will help determine if there is a potential for damaging grasshopper densities the following season. Beginning in the spring, nymphal surveys in high risk areas identified the previous fall will allow park personnel to monitor populations that show the greatest potential for problems.

2. Threshold/Action Population Levels:

A. House and Field Crickets - Threshold and action levels for crickets suggested here are arbitrary, as there are no published guidelines that deal with nuisance crickets. If crickets are indoors and damage to food, fabric, or other items is discovered, action should be taken immediately. If there are no visible signs of damage, action levels will need to be determined by park personnel by correlating cricket densities with staff complaints.

If field crickets threaten gardens or other valuable plants outside, action levels must be determined by weighing the desirability of management measures against the aesthetic or other value of the threatened plants, taking into account such factors as the season and the stage of development of the plants. In general, if cricket densities of greater than 5 large individuals per pit-fall trap per night are encountered for 3 consecutive nights, and the plants are at a susceptible stage such as the start of fruit or seed set, management measures may be required.

B. Mormon Crickets - APHIS has set the threshold for Mormon crickets at 8 per square yard, but that figure is flexible and depends on the ability of the affected land to withstand damage (C. Bare, personal communication). Because they are natural components of park ecosystems, one criterion for use in the NPS might be to prevent undue economic impacts on adjacent land (J.L. Kennedy, in litt.).

C. Melanoplus spp. - The APHIS threshold for grasshoppers is 8 per square yard. However, recent research indicates that the APHIS action levels can be considerably refined by taking into account the value of the forage, the average amount eaten by the grasshoppers, the cost of management, and other factors (Onsager 1984). See also 2.B.

3. Management Alternatives-Nonchemical:

A. House and Field Crickets - Most cricket management problems can be solved through the use of cultural management methods. These are detailed in Carr (1982), and may be divided into exterior and interior controls:

1. Exterior - Reduce cricket harborage by keeping lawns mowed and gardens close to buildings weeded. Remove woodpiles stacked against buildings to at least 1 ft away and keep the space between clear of weeds and debris. A layer of ashes applied in a band around the base of the wood pile will help decrease its attractiveness to crickets. Keep shrubs and other harborages away from building entrances. Fill the space between the building foundation and the soil with gravel. Garbage cans should be raised off the ground on pallets or other supports and the space beneath them kept free of litter. If large populations of crickets are developing in garbage dumps or trash heaps, the dumps should be removed or buried. Outdoor lighting should be eliminated or reduced where feasible, or yellow "bug" lights used in place of white incandescent or fluorescent lights. Buildings should be inspected for openings near ground level that might allow crickets to enter. Weather strip doors and windows, especially window wells. Screens, and vents should be repaired if they are not tight fitting. Holes should be caulked or plastered. Corrective measures should be taken to repair clogged drainpipes or other problems which cause moisture buildup near the foundation.

2. Interior - Repair leaking pipes or other sources of moisture to deny the crickets water. Repair loose-fitting baseboards, seal cracks, and tighten the fit of cabinet doors. Doors of closets which have spaces at the bottom should be made tight fitting to deny crickets access to stored items. Clean up cellars and basements; remove trash, sweep and vacuum up debris, and maintain a high level of cleanliness. If crickets have damaged food, discard it, and in the future store food in sturdy containers with tightfitting lids.

No biocontrol agents are recommended for these insects. However, the microsporidian Nosema locustae has been found to infect field crickets, but not house crickets (Henry and Oma 1981).

B. Mormon Crickets - Prescribed fire in egg bed areas after hatching of Mormon crickets may be an effective cultural control in some localities, particularly since the egg bed areas are quite small and, once located, are easily definable (J.L. Kennedy, in litt.).

Nosema locustae has been found to cause death of Mormon crickets (Henry and Oma 1981), and is available in a commercial preparation from the following source:

Reuter Laboratories
14540 John Marshall Highway
Gainesville, Virginia 122065
Attn: Carter Marantette

(703) 754-4167

Consult with your Regional or WASO IPM Coordinator to determine the suitability of biological control measures for your Mormon cricket management program.

C. Melanoplus spp. - Various methods of cultural control may be used where appropriate in grasshopper management programs. Tilling the soil can bury eggs so deep that hatching will not occur, or it can bring the eggs to the surface where they are exposed to drying by the sun and wind, and to feeding by predators. Tillage can also make the earth unattractive for oviposition. Fall is the most effective time to attempt grasshopper management by tillage.

Early spring planting helps reduce the impact of grasshopper feeding later in the season, since the plants have had a longer time to mature.

Weedy field margins, roadsides and fence rows are favored grasshopper egg-laying sites. Plant perennial grasses, such as crested wheatgrass, in these areas.

Some varieties of sorghum, such as sorgo and kafir, are resistant to grasshopper attack after reaching over 8 inches in height. In localities where grasshopper outbreaks are severe, substitute these crops for more susceptible small grains.

More details on methods of cultural control are available in Anonymous (1977) and Pfadt (1978).

Nosema locustae is registered for use against grasshoppers. See 3.B for information on obtaining N. locustae. It should be applied when grasshoppers are young (i.e., 3rd to 4th instars), because it takes two or more weeks to take effect. Since grasshopper outbreaks tend to occur in 8 to 10 year cycles, a single, properly timed application of N. locustae could give up to 10 years of control (J. A. Onsager, personal communication). Research on the efficacy of N. locustae as a biocontrol agent for grasshoppers is carried out at the Rangeland Insects Laboratory of the USDA in Bozeman, Montana.

4. Management Alternatives-Chemical:

A. House and Field Crickets - Many chemicals are registered for use against crickets in buildings. The timing of chemical use is very important; chemicals are not needed until late summer, if at all. Several boric acid products, Dri-Die® (silca gel and fluosilicate), and Drione® (silica gel and pyrethrins) are registered for cricket management and may be used around stoves, furnaces, or other large appliances that are difficult to move, and may be blown into cracks or behind baseboards. Allethrin, chlorpyrifos, diazinon, pyrethrins, and resmethrin are also registered for application as sprays or dusts around baseboards or in cracks.

B. Mormon Cricket - Consult with Regional or WASO IPM Coordinator concerning chemical control of this species.

C. Melanoplus spp. - Nosema locustae may be used in combination with carbaryl on a bran flake bait

(Onsager et. al. 1980). Carbaryl and malathion are registered for use separately on bran bait. These should be applied when hatching of the target species is completed and before egg-laying begins.

Consult with your Regional or WASO IPM Coordinator to determine which chemical, if any, is suited to your cricket and grasshopper management program.

5. Summary of Management Recommendations:

Keep records of all important infestations of any pests, and the management measures taken and their effectiveness.

A. House and Field Crickets -

a. Begin monitoring when crickets are seen or when males are heard singing. Use auditory and visual techniques to locate harborages; set up pitfall traps if necessary. If populations are large (i.e., 5 or more males singing per night per room, or 2 or more crickets captured per trap per night), look for signs of cricket feeding damage to food, fabrics, or other items.

b. If action levels are reached, undertake cultural controls to eliminate food and moisture sources indoors, and reduce harborages indoors and out. Seal cracks, fix loosefitting doors and windows, and reduce outside lighing or use "bug" lights.

c. If the situation warrants, consider use of a registered pesticide.

B. Mormon Cricket -

a. Monitor Mormon crickets beginning in the spring. Record densities, locations, stages of growth, feeding habits, mating and oviposition activity, predators and parasites, and presence or absence of endangered species in cricket habitats.

b. If Mormon crickets must be controlled, consider use of prescribed burns in egg bed areas after eggs hatch. Consider application of Nosema.

C. Melanoplus spp. -

a. Monitor grasshopper populations in areas where outbreaks have occurred in the past or where high densities have been noticed by park personnel. Estimate densities using quadrat method.

b. If grasshoppers have reached damaging levels in recent years, apply cultural control methods: mow weedy roadsides to reduce feeding grounds; plant forbs or other non-preferred plants in bare or eroded areas; till open areas where grasshopper eggs are buried in the soil. Consider use of Nosema locustae as potential long-term biocontrol agent.

c. If grasshoppers threaten endangered species, historically important areas, or an outbreak that would spill over onto non-park property consider application of Nosema in combination with carbaryl or malathion, or consider use of carbaryl or malathion alone on treated bran bait for immediate control.

Consult with your Regional or WASO IPM Coordinator to determine which pesticide, if any, is best suited to your cricket and grasshopper management program.

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V. PERSONAL COMMUNICATIONS

Chuck Bare
Animal and Plant Health Inspection Service
United States Department of Agriculture
Beltsville, Maryland

Joe L. Kennedy
Superintendent
Dinosaur National Monument
Dinosaur, Colorado

Dave A. Nickle
Curator of Orthopteroid Insects
Department of Entomology
Smithsonian Institution
Washington, D.C.

Jerome A. Onsager
Director of Research
Rangeland Insect Laboratory
United States Department of Agriculture
Bozeman, Montana

VI. SAMPLE CRICKET AND GRASSHOPPER SURVEY FORM
(Adapted from Plant Protection and Quarantine Form 370.)

PARK

DATE | MONITOR(S)

Sq. ↓	STOP NUMBER														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
TOT															
#/m^2															

Total grasshoppers from 18 squares divided by 2 = #/m^2 (or #/ft^2).

(OVER)

Sample Cricket and Grasshopper Survey Form
(back page)

Stop No.	Location (be specific)	Notes* (species, food plants, weather, temperature, time, habitat, etc.)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

* Use additional sheets for notes where necessary.

NATIONAL PARK SERVICE
IPM Information Package

DUTCH ELM DISEASE

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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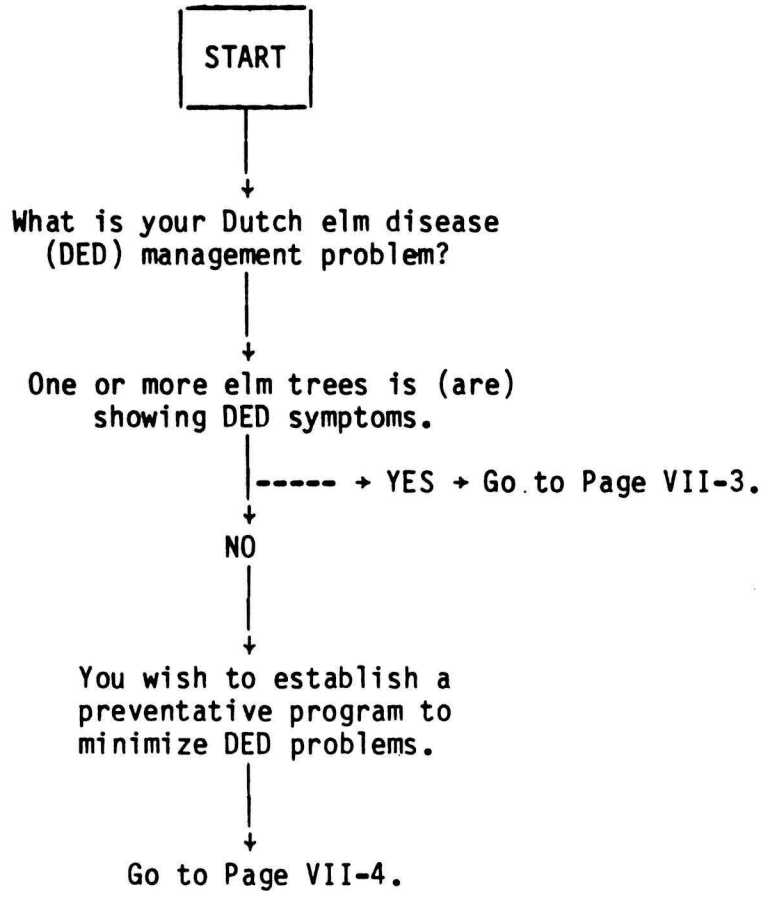
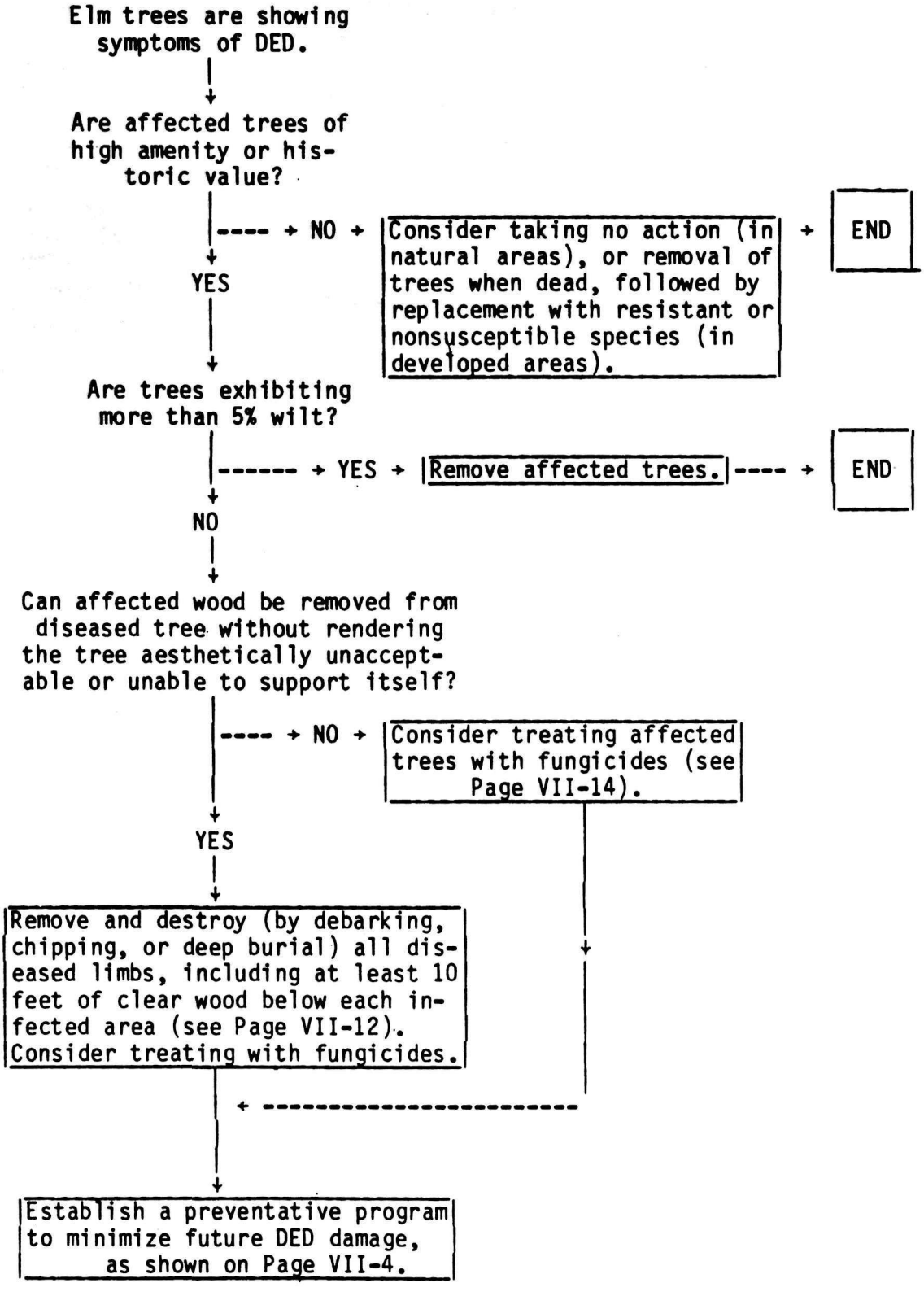
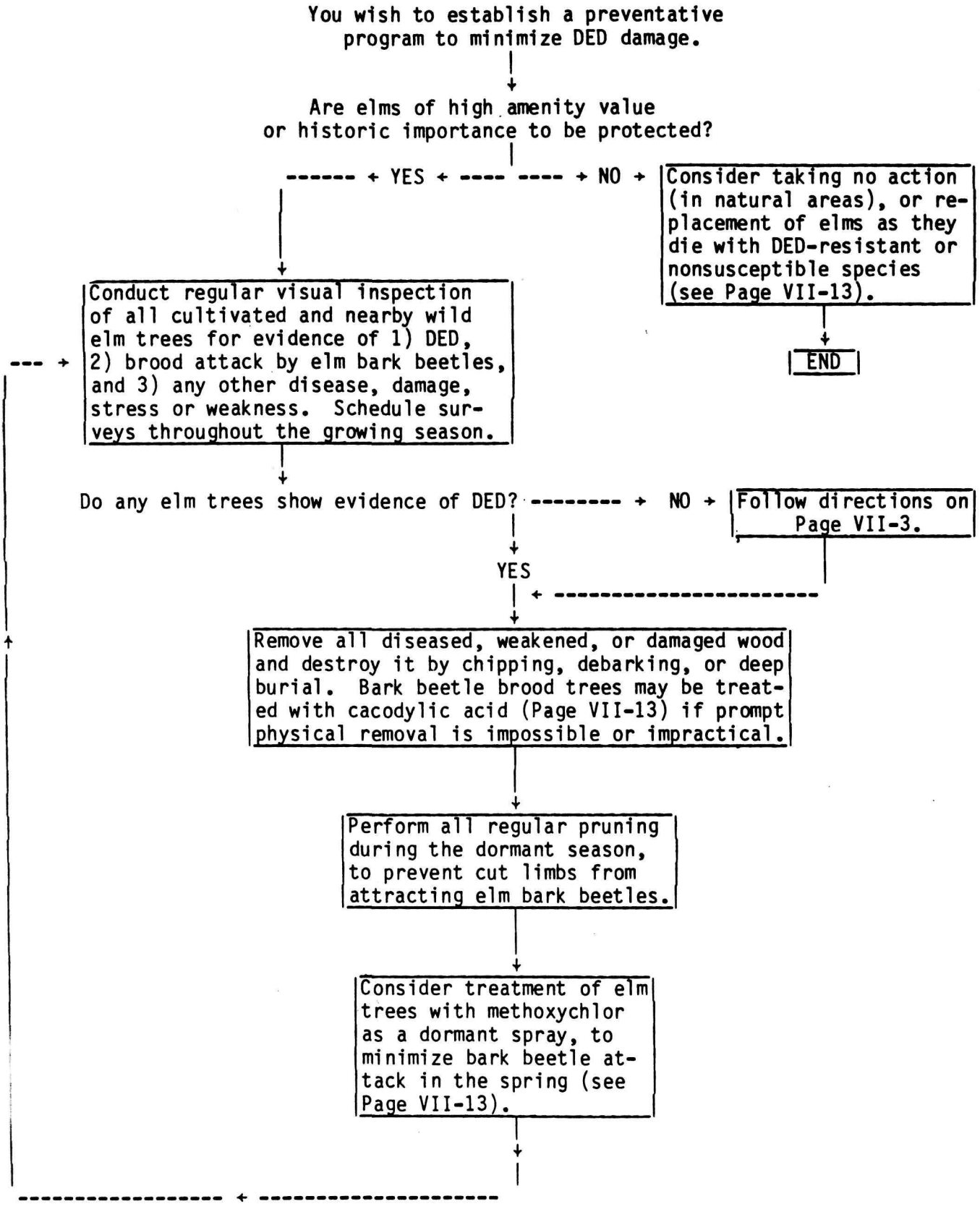
I. DUTCH ELM DISEASE IPM DICISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




Elm trees are showing symptoms of DED.
Are affected trees of high amenity or historic value?
NO
Consider taking no action (in natural areas), or removal of trees when dead, followed by replacement with resistant or nonsusceptible species (in developed areas).
END
YES
Are trees exhibiting more than 5% wilt?
YES
Remove affected trees.
END
NO
Can affected wood be removed from diseased tree without rendering the tree aesthetically unacceptable or unable to support itself?
NO
Consider treating affected trees with fungicides (see Page VII-14).
YES
Remove and destroy (by debarking, chipping, or deep burial) all diseased limbs, including at least 10 feet of clear wood below each infected area (see Page VII-12). Consider treating with fungicides.
Establish a preventative program to minimize future DED damage, as shown on Page VII-4.


You wish to establish a preventative program to minimize DED damage.
Are elms of high amenity value or historic importance to be protected?
YES
NO
Consider taking no action (in natural areas), or replacement of elms as they die with DED-resistant or nonsusceptible species (see Page VII-13).
END
Conduct regular visual inspection of all cultivated and nearby wild elm trees for evidence of 1) DED, 2) brood attack by elm bark beetles, and 3) any other disease, damage, stress or weakness. Schedule surveys throughout the growing season.
Do any elm trees show evidence of DED?
NO
Follow directions on Page VII-3.
YES
Remove all diseased, weakened, or damaged wood and destroy it by chipping, debarking, or deep burial. Bark beetle brood trees may be treated with cacodylic acid (Page VII-13) if prompt physical removal is impossible or impractical.
Perform all regular pruning during the dormant season, to prevent cut limbs from attracting elm bark beetles.
Consider treatment of elm trees with methoxychlor as a dormant spray, to minimize bark beetle attack in the spring (see Page VII-13).

II. DUTCH ELM DISEASE BIOLOGY AND ECOLOGY

1. Disease Described:

Dutch elm disease is caused by the fungus *Ceratocystis ulmi*. For a complete description of the pathogen, see Agrios (1969) or Stipes and Campana (1981). The first symptoms of DED are sudden or prolonged wilting of the leaves of individual branches (occasionally of an entire tree). Wilted leaves may curl, turn yellow, then brown, and finally fall or remain attached to their branches. DED usually appears initially on one or more branches, and spreads to other portions of the tree. Affected trees may die branch by branch over a period of years, or may develop symptoms over the entire tree and die within a single growing season. Trees infected in the spring or early summer are likely to die quickly; those infected later in the growing season are usually less severely affected, but may die during the following year.

If the bark is peeled back from infected twigs or branches, brown streaking or mottling is visible in the outer layers of wood. In cross section, the discoloration appears as a broken or full ring in the outer growth rings.

2. Geographic Distribution:

C. ulmi is an exotic pest which may have originated in Asia. The first known cases of DED in the U.S. were found in Cleveland and Cincinnati, Ohio, in 1930; the fungus had apparently been brought into the U.S. in elm wood imported from Europe. Since then, the disease has spread throughout the U.S., except for the states of Florida, Louisiana, Arizona, New Mexico, Utah and Nevada. A new, more aggressive strain of the fungus appeared in Canada in the 1960's, and has spread throughout the eastern U.S. during the 1970's.

3. Habitat:

C. ulmi can exist throughout the range of susceptible host trees.

4. Hosts:

All species of elms (genus *Ulmus*) are attacked by DED. The American elm, which is the most valuable native species, is one of the most susceptible. Certain elm species appear to have limited resistance to *C. ulmi* (see Page VII-12).

5. Disease Cycle:

A. Overwintering - C. ulmi overwinters in the bark of dying or dead infected trees and logs as mycelium or spore-bearing structures (coremia).

B. Spread to Healthy Trees

1. Root Grafts - C. ulmi can move directly from diseased to healthy trees through natural root grafts that commonly form between adjacent trees, especially those growing less than 50 feet apart. The fungus is carried (as spores) or grows (as mycelium) directly from the vascular tissues of the infected tree to those of the healthy tree through their connection at the graft.

2. Vectors - The vectors of C. ulmi are species of elm bark beetles (Scolytidae), since they visit and create wounds in the sapwood of healthy elm trees. The Scolytids which vector C. ulmi in the U.S. are the European elm bark beetle, Scolytus multistriatus, and the American elm bark beetle, Hylurgopinus rufipes. For a description of these species see Agrios (1969) or Stipes and Campama (1981). The European elm bark beetle was introduced into North America before the 20th century, along with S. mali, which prefers to breed in apple and cherry trees, so is of only secondary importance (Stipes and Campana, 1981). S. multistriatus has replaced H. rufipes as the major vector of C. ulmi in areas of the U.S. where winter temperatures do not fall to -6°F (which kills overwintering larvae of S. multistriatus). H. rufipes is still an important vector in Minnesota, Wisconsin, Maine, Northern New York and New England, and most of Canada.

Damaged or weakened elm wood releases attractants which lure adult elm bark beetles. The beetles tunnel into the inner bark to breed. Virgin female European elm bark beetles produce two additional aggregating pheromones which attract large numbers of males and females to the tree; American elm bark beetles are not known to produce these pheromones. Millions of beetles may attack a single elm. Each female beetle tunnels between the bark and sapwood of the brood tree, laying a row of eggs on each side of her "maternal gallery". Up to 100 eggs may be produced by a single female. The direction of the maternal gallery is species specific: those of S. multistriatus run parallel to the grain of the wood, while those of H. rufipes are oriented at a 45° angle to the grain.

Larvae hatch from the eggs in about a week; the white, legless grubs tunnel perpendicularly to the direction of the maternal gallery, feeding on elm phloem cells for 4-5 weeks. Pupation lasts about 1-2 weeks, after which the red-brown, 1/8" adult beetles emerge from the trees through small holes. New adults become contaminated with C. ulmi spores as they tunnel through the brood tree toward the surface. The fungus grows throughout the insects' tunnels, producing coremia with their sticky spores; as the beetles pass through the tunnels, thousands of spores adhere to their bodies.

After emergence from the brood tree, adult beetles fly to healthy elms to feed, or to declining elms to breed. Adult beetles may fly up to 400-600 yards from their emergence tree before attacking a brood tree. If picked up by air currents, adult beetles may be carried 20-50 miles (G.N. Lanier, personal communication) before landing to breed.

Scolytus beetles often feed on or tunnel into twig crotches in the crowns of healthy elms; healthy twigs 1-1 1/2 years old seem to be preferred (Stipes and Campana, 1981). In early summer, most feeding occurs at the junction of a current shoot and the previous year's growth; late season injury is often on new shoots at the bases of leaf petioles. H. rufipes feeds on larger branches, up to about 4 inches in size. During the feeding period, fungal spores may be introduced into the new host trees.

Bark beetles frequently feed on logs cut for lumber and fuel. Such colonized wood may become reservoirs for C. ulmi, even if the wood is of a resistant species (e.g., Siberian elm).

Breeding attacks frequently occur on elm trees with recently broken, stressed, or pruned limbs. Such trees often become infected by C. ulmi whether or not the beetles successfully establish broods.

S. multistriatus commonly produces two generations per year; the first overwinters as larvae, pupates in early spring, and emerges as elms reach full leaf. The second generation flies in late summer, producing the broods that overwinter. H. rufipes usually overwinters as adults in the bark at the bases of healthy elms, and may cause C. ulmi infections during fall feeding in lower boles, or during spring feeding in branches. H. rufipes may produce

one or one and one-half generations per year (overwintering as larvae or adults in alternate years), depending on the duration of warm weather (Stipes and Campana, 1981).

C. Development Within The Host - When spore-laden bark beetles tunnel through the bark and wood of elm stems, C. ulmi spores are deposited into wounded tree tissues, germinate rapidly, and grow into the bark and wood. When the fungus reaches the large xylem vessels of spring wood, it produces single-celled spores which are carried up the sap stream. These spores reproduce by budding, to begin new infections. Symptom development follows the vascular invasion front. Initially, only the xylem vessels and associated cells are affected. Eventually, the mycelium invades nonvascular tissues, growing intercellularly through the parenchyma.

D. Reaction Of The Host - Infected elm trees react to the presence of C. ulmi with a series of responses. Sticky gums are produced in affected cells, which block up some vessels. Outgrowths of vessel parenchyma cells (tyloses) grow into vessels through pits and block the vascular system. Walls of affected cells become brown, due to toxins secreted by the fungus and to enzymatic activity of the injured cells.

Infected twigs and branches wilt and die rapidly, due to a mechanism which is not understood, although blockage of the vascular system no doubt contributes to the wilt.

Spring or early summer infections result in invasion of the large springwood vessels, allowing rapid transport of fungal spores throughout the tree. If the vascular infection becomes general, the tree may die in a few weeks. Later infections are usually limited to the narrower summerwood vessels, resulting in slower fungal movement, and localized damage which may not become serious until the following season.

6. Seasonal Abundance:

A. Vectors - Elm bark beetles usually overwinter as larvae, but the American bark beetle also may overwinter as adults. In Syracuse, New York, populations of adult S. multistriatus were observed to peak in June, August (the largest peak), and September (the smallest) (Stripes and Campana, 1981). H. rupifes adult populations peaked in April (emerging overwintering adults), July-August, the following

June-July, and from August to frost of the second year. In Washington, D.C., S. multistriatus overwinters as larvae, emerging in May-June to produce a second generation which emerges in July-August (and, in mild weather conditions, a smaller emergence in the fall)(Sherald, 1982).

B. Pathogen - C. ulmi grows and sporulates in elm tissues throughout the growing season. Spread from tree to tree through root grafts does not require vectors, so can occur any time that temperatures are high enough to permit fungal growth. Host trees are most susceptible to infection in late spring and early summer, when large springwood xylem vessels have been produced.

7. Responses to Environmental Factors:

The sporulation of C. ulmi is temperature-related. Asexual spores are most commonly produced during the warm months; coremia are most frequent from July through October. When sexual reproduction occurs (it is rare in nature), the production of fruiting bodies (perithecia) increases with falling temperature, and is most common between November and February.

8. Impact of Dutch Elm Disease:

8.1 Direct Impact:

Prior to the introduction of DED into the U.S. in 1930, the American Elm (U. americana L.) was one of the most popular street trees throughout the Northeast, Middle Atlantic, and Midwest regions; approximately 77 million elms were growing in incorporated areas in the U.S. By 1976, about 43 million of those trees had been lost to DED (USFS, 1977). An additional impact of DED is the loss of shade and aesthetic beauty in formerly elm-planted urban areas. The impressive shape, size, fall color, and shade quality of the American elm led to the institution of a near monoculture of this species in urban areas, which has served to enhance the spread of DED.

8.2 Indirect Impact:

The major indirect impact of DED is the cost of removal and replacement of elm trees which have been killed. Sherald (1982) reported that the estimated costs of these procedures may be as much as $100 million annually in the U.S.

9. Natural Enemies:

A. Pathogen - Strobel and Lanier (1981) reported moderate success in controlling DED in small scale tests by injecting trees with the bacterium *Pseudomonas syringae* van Hall, a plant pathogen that inhibits *C. ulmi in vitro*. O'Brien et al. (1984) attempted to obtain control by injecting trees with isolates of *Streptomyces* spp. which were inhibitory to the fungus *in vitro*; no prevention of DED was found.

B. Vectors - The following predators and parasites are known to attack *S. multistriatus* in the U.S. and Canada: the wasps *Dendrosoter protuberans* (introduced), *Spathius canadensis*, *Entodon leucogramma* and *Cheiropacus colon*; the flies *Lonchaea polita* and *L. ciliata*, and the mite *Pymotes scolyti* (Pfadt,1978; Save the Elms Task Force, 1983). None of these organisms is known to provide effective levels of biological control of this beetle. Although *H. rufipes* is a native beetle, no naturally-occurring agents are known which can provide useful levels of control of this beetle.

III. DUTCH ELM DISEASE MANAGEMENT

1. Population Monitoring Techniques:

C. ulmi does not produce wind-or water-borne spores, and only develops mycelium inside infected trees or logs. Therefore, direct monitoring techniques for the fungus would not be useful. The best monitoring technique is visual observation of trees for DED symptoms (wilt of isolated branches or a general wilt accompanied by vascular discoloration). Since these symptoms are produced by other wilt diseases as well (Stripes and Campana, 1981), it may be useful to collect samples of infected material for analysis by an extension or state university plant pathologist.

The use of sticky traps to monitor populations of elm bark beetles is currently under investigation (Lanier, 1983 and personal communication).

2. Threshold/ Action Population Levels:

Due to the aesthetic importance of the American elm in urban settings, the widespread distribution of *C. ulmi* and its insect vectors, and the likelihood of root-graft transmission throughout an elm grove or row once any member tree becomes infected, the presence of *any* diseased branches or limbs indicates that management procedures must be initiated.

3. Management Alternatives - Nonchemical:

A. Sanitation - The single most effective way to prevent or minimize new infections of *C. ulmi* is sanitation. The goals of sanitation are:

1. The eradication of known sources of disease, by destroying all diseased trees and tree parts; and

2. Reduction of the inoculum potential of *C. ulmi* by making all wood which could support fungal growth and sporulation unusable by the pathogen; and

3. Reduction of the vector potential of bark bettles by destroying all elm wood attractive to beetle attack, including elm branches or stems weakened, dying, or dead from *any* cause.

An effective sanitation program must include the following:

1. Making regular visual surveys for DED symptoms throughout the growing season, beginning when elms leaf out in the spring, and continuing until dormancy in the fall.

2. Rapidly removing and destroying all diseased trees, and pruning diseased limbs; at least 10 feet of nondiscolored wood must be removed below the point of symptom expression, to ensure that tissues harboring fungal spores and mycelium are removed from the tree. Pruning may be combined with fungicidal injection (see Page 13). Pruning should be performed immediately (tree removal within 20 days) after disease detection (Sherald, 1982). Root grafts (see below) must be destroyed before a diseased tree is removed, to prevent diseased sap from flowing into adjacent healthy trees after the trunk of the diseased tree is cut.

3. Destroying all wood removed by chipping, deep burying, burning, or debarking; this renders the wood unfit for colonization by bark beetles.

4. Performing regular pruning of elm trees only during the dormant season (October to February), so that pruning cuts will not attract bark beetles.

5. Sterilization of all pruning tools before each cut by dipping in denatured alcohol or chlorine bleach, to prevent infection of healthy wood by spores contaminating tool surfaces.

B. Root Graft Interruption - When diseased elm trees are found within 50 feet of healthy elm trees, root grafts between the diseased tree and surrounding trees must be destroyed or prevented. A trench 36-40 inches deep (the width of the trench is not critical) between trees will sever nearly all root grafts, since most large elm roots are found within 2 feet of the soil surface. The trench can be backfilled immediately after it is dug. Trenching between the first and second closest healthy trees will add an extra degree of safety, in case the closest tree has already been infected.

C. Irrigation - In arid areas (especially in the Western U.S.), the provision of sufficient water for proper elm growth may reduce drought stress, which can promote bark beetle attack, resulting in DED.

D. Resistance - Although all elm species are attacked by C. ulmi, not all are as severely affected as is the American elm. Among those species in which

resistance has been found are the Smooth-leafed elm (U. carpinifolia cvs.), Dutch elm (U. x hollandica), Chinese elm (U. parvifolia), Siberian elm (U. pumila), Himalayan small-leafed elm (U. villosa), and hybrids of these species (such as the urban elm [(U. x hollandica 'Vegeta' x U. carpinifolia) x U. pumila] and Sapporo Autumn Gold elm [U. pumila x U. japonica]). Hybridizing any of these with the American elm is difficult (because the American elm is tetraploid). Most resistant species do not have the distinctive shape and/or the cold hardiness of the American elm. None of the resistant species is completely resistant to all strains of the fungus, so any could be destroyed in the future by different races of C. ulmi.

E. Replacement with Other Species - The extreme reliance of urban planners on the American elm created the monoculture that permitted the rapid spread of DED throughout the U.S. Replacement of destroyed elms with other large shade trees will dilute this monoculture, reducing the rate of spread of DED among remaining elms. The more diverse urban plantings become, the smaller are the risks of extensive loss due to single factors such as DED.

Japanese zelkova (Zelkova serrata) has been suggested as a replacement for elms, because its size and shape are similar to those of American elm and because it is less susceptible to DED than is the American elm. Weeping linden (Tilia petiolaris) has an effective shape and is not affected by C. ulmi.

4. Management Alternatives-Chemical:

A. Cacodylic Acid - Destruction of an elm bark beetle-infested tree can be performed before cutting by applying cacodylic acid in cuts around the trunk, or by injection into root flares. Treatment should be performed while the tree is in leaf to enhance translocation. Cacodylic acid causes rapid drying of the wood, and destroys beetle eggs and larvae. This technique can be used in natural areas or other locations where tree removal must be delayed or is impractical.

B. Insecticides - Application of insecticides to all bark surfaces of dormant elm trees can prevent C. ulmi infection by preventing beetle feeding. Methoxychlor is routinely used for mist blower (at 12.5% active ingredient) or hydraulic sprayer (2% AI) application. Follow all label directions.

C. Fungicides - Since C. ulmi grows inside the tree, normal foliar fungicide application is not effective against it. Injection of fungicides such as Arbotect 20-S and Lignasan-BLP directly into affected limbs and trunks may be effective in controlling DED. However, injection produces wounds which may become infected by various organisms. Fungicides can aid pruning therapy, if the treatment is applied to the affected limb(s) and trunk 2-10 days prior to removal of the limb(s) (Sherald, 1982). Contact your Regional or WASO IPM Coordinator for more information.

D. Root-Graft Destruction - Grafts may be destroyed by application of the soil-fumigant Vapam (SMDC) to holes drilled into the soil between trees. See Sherald (1982) for a discussion of recommended methods. Follow all label directions.

E. Elm Bark Beetle Trapping - The bark beetle attractants produced by stressed elm wood and by female European bark beetles have been synthesized. Lanier (1978) has studied the effectiveness of these attractants as baits to lure beetles to sticky cardboard traps. He reported that the use of such baited traps on utility poles and nontarget trees may be effective in reducing DED in elm groves. Testing of beetle trapping for protection of high-value elms is currently underway in the Washington, D.C. area (Lanier, 1982; Lanier, 1983). Sticky traps and attractant formulations are available from DeWill, Incorporated, Riverside, Illinois (DeWill Elm Bark Beetle Trap and Entrap Insect Lure, respectively). Contact your regional IPM Coordinator for further information.

5. Summary of Management Recommendations:

A. Where American elm trees must be maintained because of historic significance or overriding aesthetic concern, the following procedures are recommended to minimize DED damage and the possibility of new infection:

1. Regular surveys for DED symptoms on cultivated and nearby wild elm trees throughout the growing season (from leafing out to dormancy);

2. Rapid removal of diseased tree parts or trees, and destruction of removed wood;

3. Chemical sanitation with cacodylic acid where removal would be delayed beyond 20 working days after discovery of disease symptoms;

4. Destruction of brood wood of elm bark beetles;

5. Destruction of root grafts around diseased elm trees and their nearest healthy neighbors;

6. Pruning of all weakened, broken, or dying elm branches and destruction of the wood;

7. Delaying of normal pruning until dormancy;

8. Treatment of dormant trees during late winter/early spring with methoxychlor, to prevent insect colonization (this may not be needed if thorough sanitation is performed on all elm trees, including wild trees);

9. Trapping of elm bark beetles using Multilure-baited adhesive traps; and

10. Replacement of destroyed elms with resistant varieties or nonsusceptible tree species.

Treatment with fungicides may be necessary in certain cases. Contact your regional NPS IPM Coordinator for approved procedures.

B. In Other Areas - Since DED is extremely widespread, and therapy of diseased trees is often expensive, it may be practical to remove elm trees as they are killed, and replace them with other large-growing shade trees. In natural areas, treatment of diseased elm trees would be difficult, and dead elms would most likely be replaced with other species immune to DED without a major impact on the forest community; therefore, we recommend no treatment for these areas.

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NATIONAL PARK SERVICE
IPM Information Package

EXOTIC WEEDS I: KUDZU, SALTCEDAR, AND BRAZILIAN PEPPER

Final Report

16 November 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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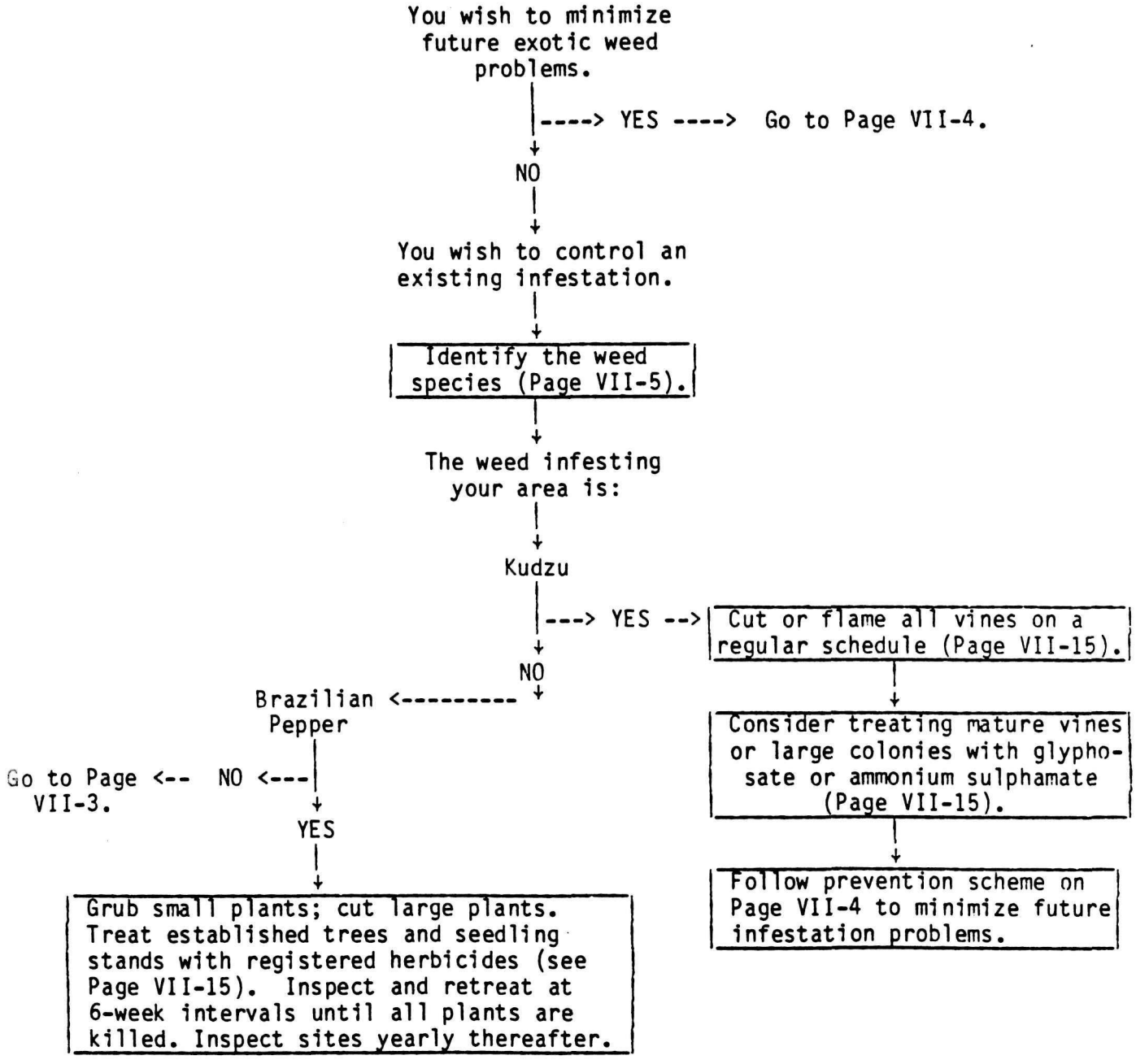
I. EXOTIC WEED IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



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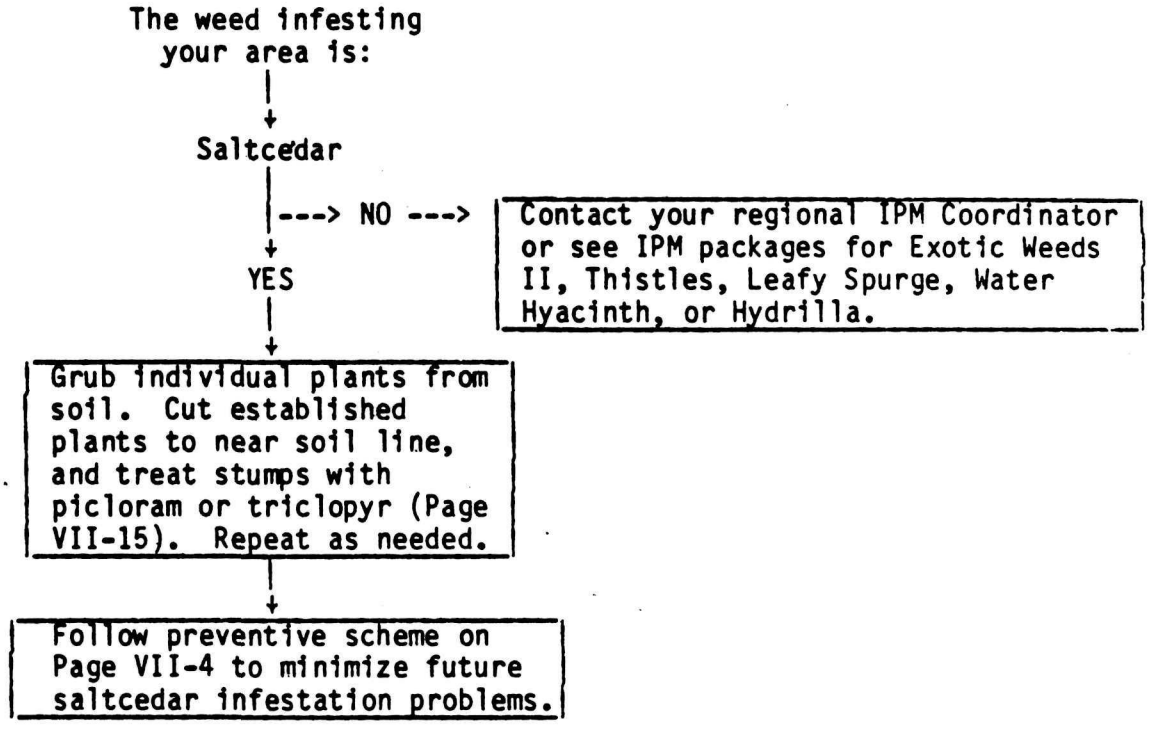

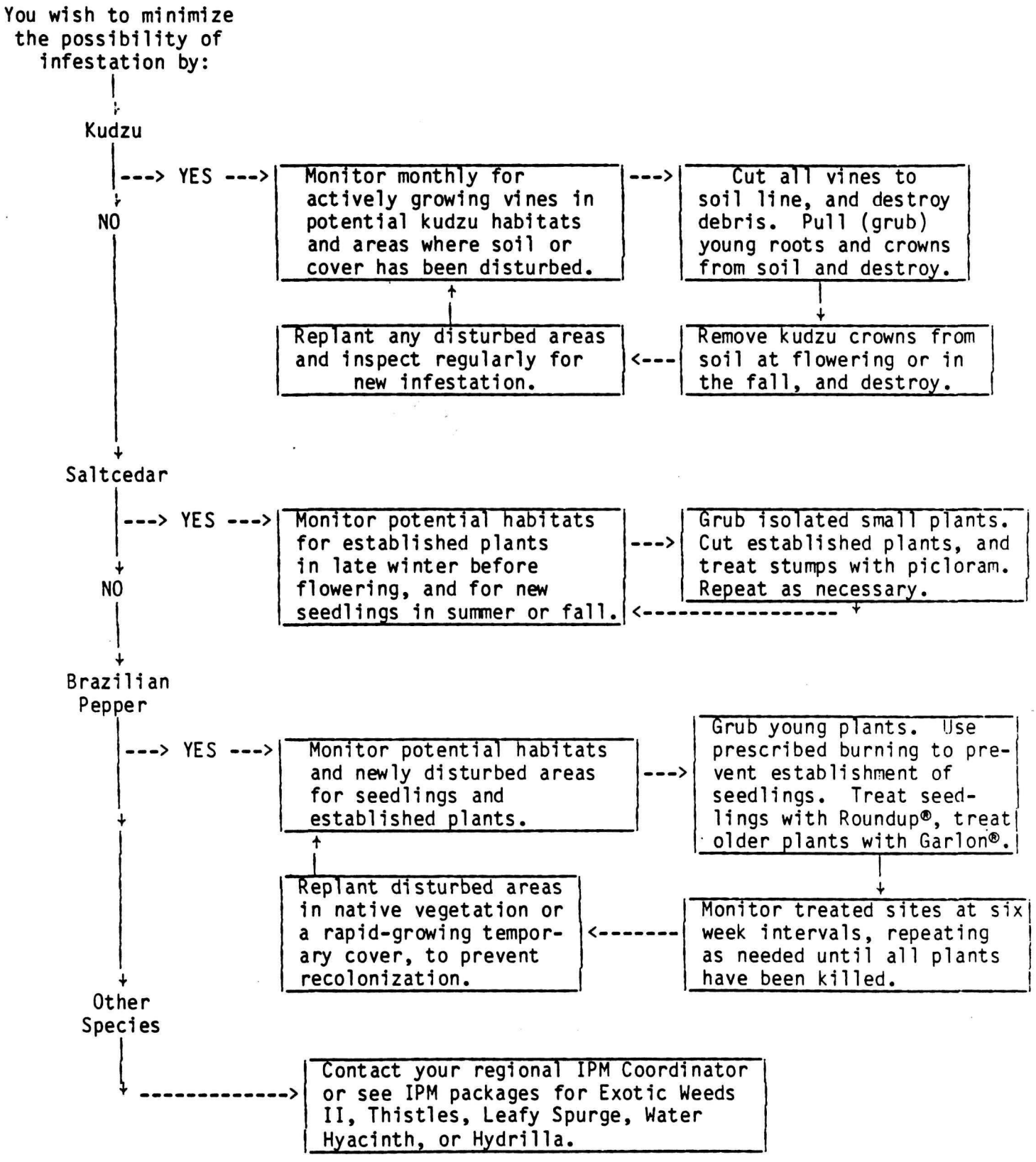
You wish to minimize the possibility of infestation by:
Kudzu
---> YES --->
Monitor monthly for actively growing vines in potential kudzu habitats and areas where soil or cover has been disturbed.
--->
Cut all vines to soil line, and destroy debris. Pull (grub) young roots and crowns from soil and destroy.
NO
Replant any disturbed areas and inspect regularly for new infestation.
<---
Remove kudzu crowns from soil at flowering or in the fall, and destroy.
Saltcedar
---> YES --->
Monitor potential habitats for established plants in late winter before flowering, and for new seedlings in summer or fall.
--->
Grub isolated small plants. Cut established plants, and treat stumps with picloram. Repeat as necessary.
NO
Brazilian Pepper
---> YES --->
Monitor potential habitats and newly disturbed areas for seedlings and established plants.
--->
Grub young plants. Use prescribed burning to prevent establishment of seedlings. Treat seedlings with Roundup®, treat older plants with Garlon®.
Replant disturbed areas in native vegetation or a rapid-growing temporary cover, to prevent recolonization.
<-------
Monitor treated sites at six week intervals, repeating as needed until all plants have been killed.
Other Species
Contact your regional IPM Coordinator or see IPM packages for Exotic Weeds II, Thistles, Leafy Spurge, Water Hyacinth, or Hydrilla.

II. EXOTIC WEED BIOLOGY AND ECOLOGY

1. Species Described:

A. Kudzu - *Pueraria lobata* (Willd.) Ohwi is a legume of the subfamily Fabaceae. It is a trailing or climbing semiwoody perennial vine reaching 32-100 ft in length. Young vines are covered with soft, fine hairs. First-year vines may reach 1/2" in diameter; old vines may reach a diameter of 4". As many as 30 vines may radiate from a single crown. Vines can grow up to 60 ft in a single growing season (and reportedly up to 1 ft per day). Vines may climb vertically as high as 50 ft, completely covering trees, buildings, or other supporting objects. During the growing season, vines are densely covered by foliage. Leaves are alternate and compound, with three broad leaflets up to 4" across, each leaflet entire or deeply 2-3 lobed and with hairy margins. Foliage drops after the first fall frost. The roots of kudzu are fleshy; the taproot may reach over 6 ft in length, 7" in diameter, and may weigh up to 400 lb.

Kudzu plants do not usually flower until their third year. Flowers are purple, fragrant, about 1/2" long, produced in long racemes, and resemble pea flowers in shape. They are produced in August and September. Flowers are followed by flattened, 2" long hairy pods which may contain 3-10 hard seeds. In the U.S., kudzu generally spreads by means of stolons (runners) and rhizomes. In addition, any vine contacting the soil will produce roots at nodes; these roots enlarge, forming new crowns. Vine cuttings and root divisions will also sprout. See Shurtleff and Aoyagi (1977) or other weed atlases for drawings of kudzu.

B. Saltcedar - *Tamarix* spp., especially *T. ramosissima* (Ledeb.), which is generally (but incorrectly) known as *T. pentandra* (Baum, 1978). Saltcedar is a deciduous shrub or small tree growing to 12-15 ft in height. Slender, long gray-green branches are spreading or upright, often forming dense thickets. Scalelike leaves are gray-green, alternately arranged, narrow, pointed, about 1/16" long, and overlap one another on the stems. The leaves often become encrusted with salt secretions. Branches take on a brown-purple color as they age. Bark is reddish-brown and smooth on young branches, becoming ridged and furrowed on older limbs. Large numbers of pink to white flowers, about 1/16" across, appear in a dense mass on 1/2-2" spikes at branch tips from March to September. Flowers are followed by greenish-yellow to pinkish-red capsules, 1/8-1/5" long, which

split into 3-5 parts on maturity. Seeds are 1/25" long, with a tuft of fine hairs at one end. The number of seeds per capsule is not constant. See Baum (1978) or Parker (1972) for drawings of saltcedar.

C. Brazilian Pepper - Schinus terebrinthifolius (Raddi). This species is a member of the Anacardiaceae, and is closely related to poison ivy. It is a broad-topped, rapidly-growing tree reaching up to 40 ft tall, with a short trunk up to 40" thick. The trunk is usually hidden by a dense head of intertwining, contorted branches. Leaves are evergreen, pinnate, and have reddish midribs which may be winged. Each leaf bears 3-13 sessile, oblong or elliptical, finely toothed, glossy, resinous, aromatic 1-2" leaflets. These are dark green on the top, and lighter on the underside. Five-petaled, white, 1/8" flowers are borne in 6" sprays originating in leaf axils along the upper 32-43" of each stem. Male and female flowers are borne on separate trees. Flowering peaks in October in Florida. Blooms are followed by masses of round, single-seeded drupes, which change from green to bright red at maturity. The appearance of the fruit is responsible for the common names "Florida holly" and "Christmas berry." See Olmstead and Yates (1984) for photographs of Brazilian pepper.

2. Geographic Distribution:

A. Kudzu - A native of Asia, P. lobata was introduced into the U.S. at the Philadelphia Centennial Exposition in 1876. Beginning in 1933, farmers in the South were encouraged to plant kudzu to reduce soil erosion. By 1953, it had become such a weed problem that is was removed from the USDA's list of permissable cover plants. In 1970, the USDA began listing kudzu as a common weed in the South. Today, kudzu is common in Alabama, Georgia, Mississippi, Tennessee, the Carolinas, Kentucky, Virginia, Maryland, and west to Texas and Oklahoma (Edwards, 1982). The weed has also been reported in New York, Illinois, Iowa, Nebraska, and Washington (Shurtleff and Aoyagi, 1977).

B. Saltcedar - This plant is a native of Eurasia and Africa that was introduced into the U.S. as an ornamental shrub in the early 1800's, and has now spread throughout the intermoutain region of the western U.S. (Carman and Brotherson, 1982).

C. Brazilian Pepper - This weed was introduced from its native Brazil in 1898 by a USDA plant explorer (Morton, 1978). It was considered an ornamental shrub and was distributed by the USDA Plant Introduction Station in Miami, FL, to local plant enthusiasts. Since then, Brazilian pepper has spread over thousands of acres of land in South and Central Florida, the Florida Keys, the Hawaiian islands, southern Arizona, and southern California.

3. Habitat:

A. Kudzu - Kudzu grows well under a wide range of environmental conditions, although best growth is achieved where winters are mild (40-60° F), summer temperatures rise above 80°F, and rainfall is abundant (40" or more). Kudzu can grow in nearly any type of soil (e.g., acid soils, lime soils, lowlands with high water tables, and over heavy subsoil), and where winter soil temperatures remain above -25°F (which temperature kills roots). Forest edges or disturbed areas such as abandoned fields and roadsides are preferred habitats.

B. Saltcedar - This species occurs in moist rangeland and pastures, bottomlands, banks, and drainage washes of natural or artificial waterbodies, and other areas where seedlings may be exposed to extended periods of saturated soil conditions. Established plants have long roots with which they can tap deep water tables, and can survive in drought conditions. Saltcedar may survive in saline soils containing up to 15,000 ppm soluble salt.

C. Brazilian Pepper - This tree quickly colonizes disturbed areas. Seedlings are shade tolerant, and can tolerate moist or saturated soils. Established plants can tolerate extended drought or inundation (up to 6 months). Apparently, Brazilian pepper can tolerate Mediterranean, tropical, and desert climates.

4. Hosts:

Not applicable.

5. Life Cycles:

A. Kudzu - Kudzu is a perennial which rarely produces seeds in the U.S. (except on plants supported vertically on buildings, trees, or other supports [Shurtleff and Aoyagi, 1977]). Establishment of new plants is by rooting of vine nodes which come in contact with soil; these roots produce new crowns, and the connection to the mother crown dies within 1 year after rooting. Kudzu is deciduous; its

leaves drop after the first frost, and new leaves are produced each spring.

B. Saltcedar - A deciduous perennial, this species annually produces seeds which are windborne to new locations. Flowers are pollinated by bees and other insects. Seedlings require extended periods of soil saturation for establishment. As seedlings become established, they develop long roots which are able to absorb water from deep below the soil surface.

C. Brazilian Pepper - This evergreen perennial produces large quantities of seeds each year. Seeds may be dispersed by birds or small mammals, or may germinate near the parent plant, producing dense spreading colonies.

6. Seasonal Abundance:

A. Kudzu - Kudzu foliage is present and vine growth occurs between early spring and the first frost. The vines are perennial, however, and are obvious year-round.

B. Saltcedar - Active growth occurs from early or mid-spring to fall, when leaves drop. Stems do not die back, forming perennial thickets which spread farther each year.

C. Brazilian Pepper - This species is evergreen, but becomes dormant during the winter months.

7. Responses to Environmental Factors:

A. Kudzu - Vines are intolerant of shade, and grow toward light. Large roots store water, allowing plants to survive in fairly dry climates (to 20" of rain per year). Growth is most rapid in acid to neutral soils (pH 4.5-7.0). P. lobata can reportedly grow in areas where winter temperatures reach -22°F; exposure to -25°F can kill roots.

B. Saltcedar - Seedlings require extended periods of saturated soil conditions for establishment; they cannot survive where water is scarce. Saltcedar can grow on soils with up to 15,000 ppm soluble salt. Established plants have among the highest known evapotranspiration rates of any desert phreatophytes (Carman and Brotherson, 1982), which may result in water depletion from the underlying soil.

C. Brazilian Pepper - Seedlings can tolerate low light levels, growing slowly until the overstory canopy is opened up. Trees can withstand extended drought, and up to 6 months of inundation. Large trees can withstand fires and high winds without suffering significant damage (Olmsted and Yates, 1984). Seedling survival is low on inundated ground.

8. Impact of Exotic Weeds:

8.1. Direct Impact:

A. Kudzu - Kudzu grows rapidly, choking out competing vegetation in sunny areas. Climbing vines may completely cover and shade out trees, and may cover and damage buildings, overhead wires, and other structures.

B. Saltcedar - Among the serious direct impacts of this species are the displacement of native range plants by its aggressive growth, the possibly serious depletion of ground water due to its rapid evapotranspiration rate, increased deposition of sediments in tamarisk-infested streams, and the blockage of streams and artificial water channels by dense clumps of saltcedar growth, which can promote flooding during periods of heavy rains.

C. Brazilian Pepper - Direct impacts include the displacement of native plants, not only because of this species' aggressive, rapid growth, but also because of allelopathic effects (toxic or inhibitory activity) of chemicals in vegetative plant parts and fruits.

Brazilian pepper is closely related to poison ivy, and can produce effects similar to that plant on humans and animals (Lloyd et al., 1977; Morton, 1978; Olmsted and Yates, 1984). Massive bird kills in Florida may have been caused by excessive feeding on Brazilian pepper berries.

8.2 Indirect Impact:

All of these species are aggressive growers, able to outcompete native plants which provide food and habitat for native animals. Replacement of the existing growth by these weeds results in a large-scale alteration of biotic communities and the potential elimination of certain species whose habitats are destroyed.

9. Natural Enemies:

A. Kudzu - In the U.S., kudzu vines may be attacked by a root knot nematode (Meloidogyne sp.), a "blackleg" fungus disease, a viral mosaic disease, and a rust fungus (Shurtleff and Aoyagi, 1977). These pests produce only minor injury, and are not known to kill kudzu plants.

B. Saltcedar - Watts et al. (1977) found only a few native insects that fed on saltcedar in New Mexico. These did little harm to the plants except under exceptional circumstances. Bugs, aphids, grasshoppers, beetles, and spider mites were among the organisms found. Watts et al. also reported two introduced insects, the leafhopper Opsius stactogalus and the scale Chionaspis etrusca, were found regularly on saltcedar. The leafhopper sometimes caused substantial damage. Baum (1978) compiled a list of insects and fungi which attack various species of Tamarix in Europe, Africa, and Asia, but found no records of enemies of T. ramosissima.

C. Brazilian Pepper - Goats can graze on foliage of this species without suffering ill effects (Morton, 1978). A witches' broom disease fungus, Sphaeropsis tumefaciens Hedges, attacks Brazilian pepper, but is also a pest of Ilex opaca, Citrus spp., and numerous ornamentals. The red-banded thrips (Selenothrips rubrocinctus Giard.) occasionally kills plants, but is also a pest of mango and cashew plantings.

III. EXOTIC WEED MANAGEMENT

1. Population Monitoring Techniques:

A. Kudzu - Regular monitoring of both developed and natural areas is required to determine the presence and extent of kudzu incursions. Since this species is a rapid grower and an aggressive competitor, these inspections should be conducted frequently (at least monthly) during the growing season.

In addition to inspecting areas for actively growing kudzu, monitors should also inspect disturbed areas, which can be rapidly colonized by the weed. All records of sightings of kudzu and of disturbed sites should be recorded, maintained, and updated at each inspection.

B. Saltcedar - Inspection of both developed and natural areas is necessary to determine the presence and extent of saltcedar incursions. One inspection should be made early in the growing season (before or at flowering), to identify mature plants and initiate control before seed can be set and distributed. Additional inspections should be made later in the growing season to identify seedlings developing from seed set in the current year. All records should be maintained and updated at each inspection.

C. Brazilian Pepper - Inspection of all likely habitats is required to determine the presence and extent of Brazilian Pepper incursions. At least one inspection per year should be made for the presence of established plants. Frequent inspections (i.e., at least monthly) should be made for the presence of disturbances in the normal plant cover (e.g., due to storms, alterations of water levels, fires, and human activities), since such sites can be rapidly colonized by this weed. All records should be maintained and updated at each inspection.

2. Threshold/Action Population Levels:

A. Kudzu - Since this weed is an adaptable, aggressive competitor which can rapidly overgrow native vegetation, the presence of any kudzu should trigger control activities. There is no acceptable population level (L.K. Thomas, Jr., personal communication).

B. Saltcedar - The presence of any saltcedar should trigger control activities, although it should be recognized that where stands are extensive, elimination is probably infeasible (P. Sanchez, personal communication).

C. Brazilian Pepper - The presence of any plants should trigger control activities, since this species is capable of displacing native vegetation.

3. Management Alternatives-Nonchemical:

A. Kudzu -

1. Cutting - Vines (including runners) are chopped just above ground level, and the pieces destroyed by burning or feeding to livestock. Early in the season, cutting is repeated at 2-week intervals, to weaken the crown and prevent resumption of photosynthesis. Later in the season, when the stored energy in the taproot has been reduced, the interval between cuttings can be extended (L.K. Thomas, Jr., personal communication). Cutting does not affect roots or crowns, which will regrow unless their supply of stored energy is depleted.

2. Flaming - A kerosene torch is played over the foliage, wilting the leaves, thus defoliating the plant. Flaming should be done according to the same schedule as cutting. Where all foliage can be reached, this method may be more effective than cutting. Like cutting, flaming does not affect the roots or crowns.

3. Burning - Destroys above-ground growth. Since kudzu vines usually will not burn during active growth (because of their high water content), vines may be flamed (see above) two or three days prior to burning. This causes the leaves to wilt and dry, providing fuel for the burning process.

4. Grubbing - This consists of mechanical removal and destruction of the entire plant, including the taproot. If all root tissue is removed, no regrowth can occur, so that repetition should not be necessary. However, this procedure can be destructive to the treated area. Removal of crowns only is more effective than cutting, but must be repeated, since remaining roots will resprout. Crown removal is most effective at flowering (when the plants are weakest) or in the fall. However, the crowns are difficult to find except in the spring, when the operation will be less effective.

5. Grazing - Kudzu is a favored food of goats and cows, which can provide useful levels of control. Where these can be accommodated in the park management plan, this technique can be effective.

B. Saltcedar -

1. Cutting - This process involves removal of all growth at ground level, but regrowth is not prevented.

2. Burning - This removes above-ground growth, but allows remaining roots and crowns to resprout.

3. Grubbing - Grubbing with a grubber blade, which is smaller than a root plow, and is used to remove smaller stands. This is less destructive than root plowing.

4. Root Pulling - Removal of the main portion of the root system and crown is labor and time intensive. Regrowth from incompletely-removed roots may occur.

5. Chaining - A chain, 360-400 ft long, and weighing 40-50 lb/ft, can be doubled and pulled between two crawler tractors. Chaining may uproot whole plants and/or may shear trunks at ground level. Drawbacks of chaining include the failure to remove all below-ground tissue, allowing regrowth; and the destructiveness of the procedure itself.

6. Root plowing - This process shears vegetation below the ground surface. The root plow kills medium to large shrubs by shearing below the crown, largely (but not completely) preventing regrowth. This technique is destructive to the environment but is widely used in areas where saltcedar coverage is nearly 100% (Gangstad, 1982).

7. Draglining - Drag lines are used to shear vegetation growing in water bodies or channel banks. It is not suitable for large vegetation.

8. Bulldozing - This shears plants at ground level, or uproots entire plants. Regrowth from sheared trunks can occur. This, too, is a destructive technique.

C. Brazilian Pepper -

1. Hand Removal - Seedlings or small saplings can be pulled from the soil. Pulled plants must be removed from their growing site and bagged or dried, to prevent resprouting.

2. Burning - Olmsted and Yates (1984) report that prescribed burning has kept a slash pine forest in Florida free of Brazilian Pepper seedlings.

3. Bulldozing - This technique has been used in the Everglades National Park (Olmsted and Yates, 1984).

4. Management Alternatives-Chemical:

A. Kudzu - Ammonium sulfamate and glyphosate are recommended for control of kudzu in the NPS. Bratton (1981) and Rosen (1982) report success controlling kudzu in two national parks using Roundup® (glyphosate) applied to the foliage two or three times each year.

B. Saltcedar - The following herbicides are registered for saltcedar control: 2,4-D; a mixture of dicamba + 2,4-D; and picloram. P. Sanchez (personal communication) reports that direct application of picloram to freshly cut stumps can provide effective control. The pesticide must be formulated in a nonevaporative (e.g., glycol) base, to prevent treated stumps from drying out before the pesticide has entered. Treatment should be repeated as necessary.

C. Brazilian Pepper - Non-woody seedlings can be treated with 2% Roundup® in water, as a foliar spray. Small woody saplings and established trees can be treated with 2% Garlon 4® (triclopyr butoxyethyl ester), applied as a spray to every major stem (complete coverage to runoff, at 12-15" above ground level). Treated sites should be monitored and surviving trees retreated at six week intervals following treatment, until regrowth no longer occurs.

Contact your regional IPM Coordinator to determine which, if any, herbicide is the best suited to your exotic weed management program.

5. Summary of Management Recommendations:

A. Kudzu - Regular cutting (or flaming, where applicable) may be sufficient to control most kudzu populations. Grubbing may control small infestations, if it will not result in too much destruction of other vegetation. Where it can be accommodated, grazing by goats may preclude the need for additional measures. For large overgrown areas, application of a recommended pesticide may be necessary.

B. Saltcedar - Individual plants can be grubbed from the soil. Cutting followed immediately by application of picloram to stump ends is the most effective means of controlling small stands of mature shrubs.

C. Brazilian Pepper - Small trees or individual seedlings can probably be mechanically pulled by workers wearing protective clothing. Prescribed burns may prevent establishment of seedlings in appropriate circumstances. Cutting and bulldozing may be useful against large trees and stands. Seedling stands and established trees may be treated with registered herbicides.

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V. PERSONAL COMMUNICATIONS

L. K. Thomas, Jr.
Research Biologist
Center for Urban Ecology
National Capitol Region
National Park Service
Washington, D. C.

P. Sanchez
Research Manager
Haleakala National Park
National Park Service
Hawaii

NATIONAL PARK SERVICE
IPM Information Package

IMPORTED AND NATIVE FIRE ANTS

Final Report

5 October 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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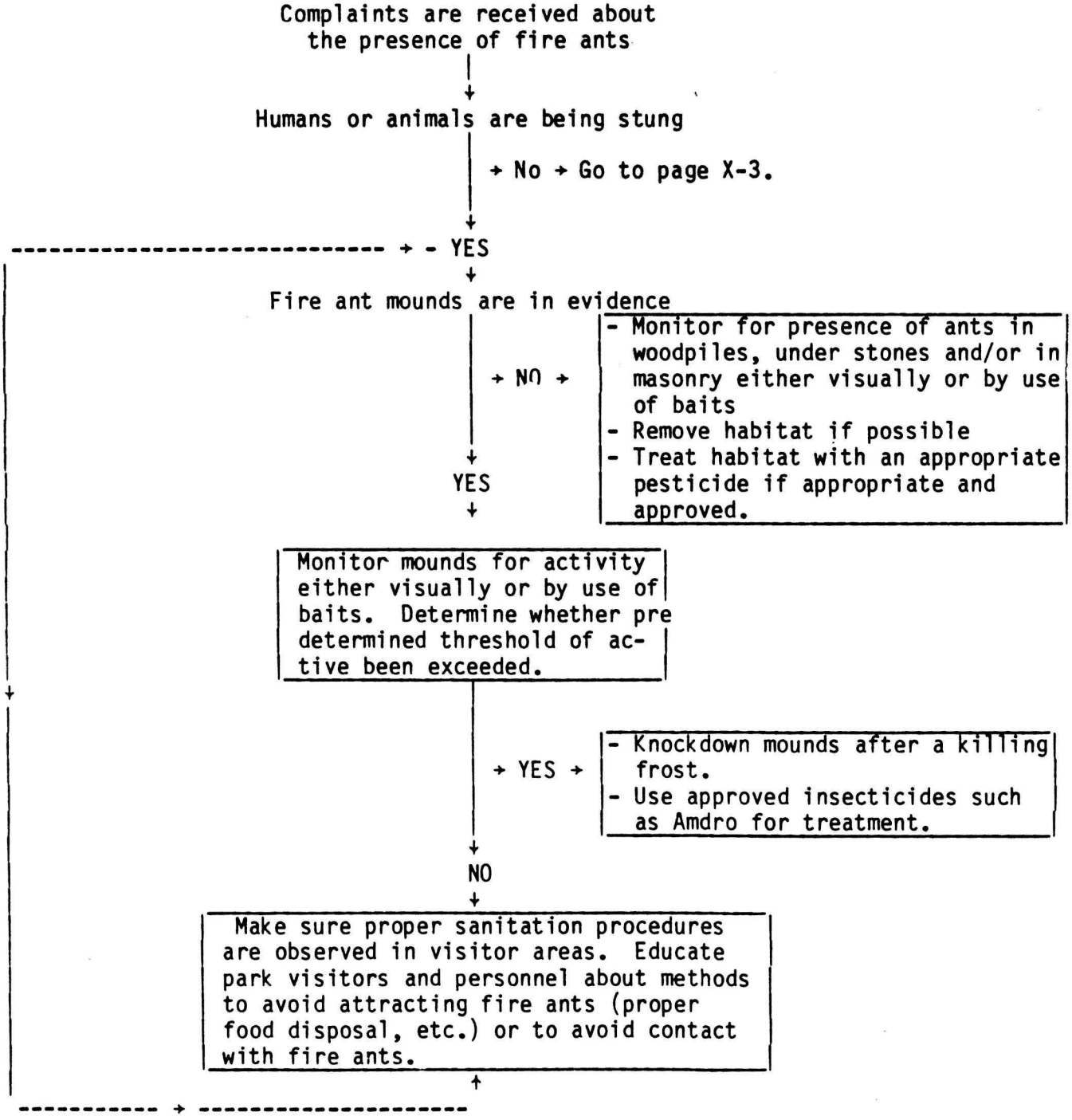
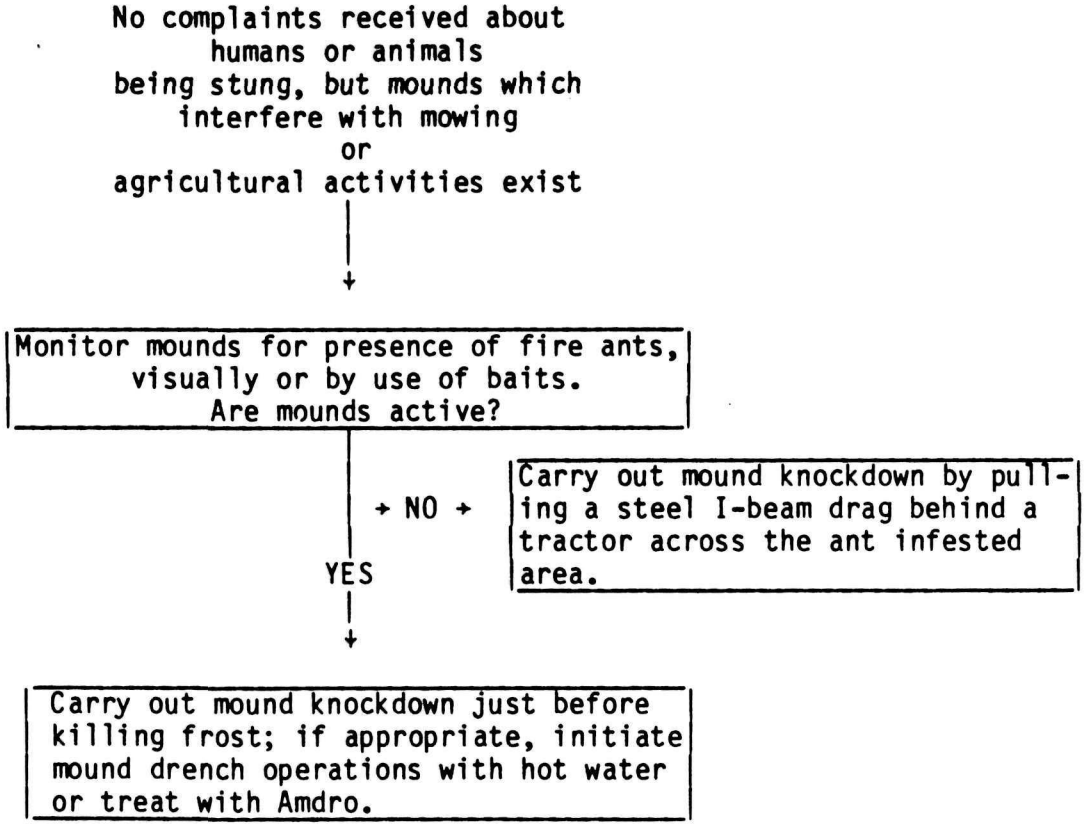
I. FIRE ANT IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




No complaints received about humans or animals being stung, but mounds which interfere with mowing or agricultural activities exist
Monitor mounds for presence of fire ants, visually or by use of baits. Are mounds active?
NO
Carry out mound knockdown by pulling a steel I-beam drag behind a tractor across the ant infested area.
YES
Carry out mound knockdown just before killing frost; if appropriate, initiate mound drench operations with hot water or treat with Amdro.

II. BIOLOGY AND ECOLOGY OF FIRE ANTS

1. Species Described:

   A. Red Imported Fire Ant - *Solenopsis invica* Buren.

   B. Black Imported Fire Ant - *Solenopsis richteri* Forel.

   C. Native Southern Fire Ant - *Solenopsis xyloni* McCook

   D. Native Fire Ant - *Solenopsis germinata* Fabricus.

   See page 119 of U.S. Department of Health, Education and Welfare (1967) for a comparative key to fire ant species.

2. Geographic Distribution

   A. Red Imported Fire Ant - Infests nearly 240 million acres in North Carolina, South Carolina, Tennessee, Georgia, Florida, Alabama, Mississippi, Louisiana, Arizona, and Texas.

   B. Black Imported Fire Ant - Found in northern Mississippi and Louisiana.

   C. Southern Fire Ant - Ranges from California, South Carolina, and Florida.

   D. Fire Ant - Most commonly found in Florida.

3. Habitat:

   A. Red Imported Fire Ant - The most important fire ant pest, it is associated with disturbed habitats, mostly created by man. Abundant in old fields, pastures, lawns, roadsides and many other open sunny habitats. Inhabits fields used for agricultural purposes where its large above ground mounds create problems in planting and harvesting crops. In areas where grass is periodically cut, colonies are flush with the ground and are hard to see. Rarely found in mature forests but is found in those disturbed by fire and storms.

   B. Black Imported Fire Ant - See 3.A. Not a good competitor against the red fire ant. May often be displaced from established habitats by the red fire ant.

   C. Southern Fire Ant - Colonies may be observed as mounds or may be constructed under the cover of stones and other objects. These ants also nest in wood or the masonry of houses.

   D. Fire Ant - Usually nests in mounds constructed around clumps of vegetation but may also nest under objects or in rotting wood.

4. Hosts:

A. Red Imported Fire Ant - A key predator of Heliothis sp. such as the cotton bollworm and tobacco budworm. Also feeds on aphids, beetles and weevils of various types, as well as ticks, horn flies and stable flies. Red fire ants have been known to attack new born rabbits, kill young quail and the young of other ground nesting birds. They have been known to attack new born livestock. Fire ants have been observed eating corn seeds planted close to the soil surface, as well as corn and pine seedlings. Human foods are also consumed.

B. Black Imported Fire Ant - See 4.A. - Shows a preference for foods with high protein content but will also feed on soiled fabric.

C. Southern Fire Ant - Practically omnivorous, feeding on seeds, flesh, juices and fruits of plants, human foods and insects. They have been known to chew insulation off telephone wires.

D. Fire Ant - See 4.C.

5. Life Cycles:

The life cycles of the various fire ant species are very similar.

1. Development of the Individual - Like all ants, the individual fire ant begins life as an egg, which hatches into a legless, grublike larval stage. The larva is a stage specialized for feeding and growing, and almost all growth occurs during this period. As in all insects, growth is accomplished by periodic molting, or shedding of the cuticle (skin). Having reached its final size, the larva becomes a pupa in which various adult structures, such as legs, and in some cases wings, become apparent for the first time. The pupal stage is the transitional stage between the larva and the adult that emerges during the final molt. In insects in general, the adult stage is specialized for reproduction and dispersal, but with ants, some adult individuals are capable of reproduction (queens and males), and the remainder are a sterile worker caste.

2. The Colony - The social unit of fire ants is the colony, and colonies, like individuals, pass through a characteristic life cycle. Fire ants are very typical of ants in general with regard to their life cycle. In addition to workers and a queen, mature

colonies contain males and females capable of flight and reproduction. These are generally termed reproductives. On a warm day following a rain, the workers open holes in the nest through which the reproductives exit on the mating flight. Mating takes place 300 to 800 feet in the air. Mated females descend to the ground, break off their wings and proceed to search for a place to dig the founding nest, a vertical tunnel 2 to 5 inches deep. They seal themselves off in this founding nest to lay eggs and to rear their first brood of workers. They do this entirely without feeding by utilizing reserves stored in their bodies. The first worker brood takes about a month to develop; these are the smallest individuals in the entire colony cycle. They open the nest, begin to forage for food, rear more workers, and care for the queen. Hereafter, the queen essentially becomes an egg-laying machine. The queen generally mates several times and may live for several years. Workers are less long lived and usually will not live for an entire season.

The colony grows rapidly by the production of workers who gradually enlarge the original vertical tunnel into multiple passages and chambers. Eventually, most species produce the familiar fire ant mound. Colony maturity is attained when reproductives are once again produced. The reproductives leave to mate and form new colonies. Mature colonies of some species of fire ants may consist of an average 60,000 workers, weighing 70 to 80 grams, but colonies of up to 150,000 or more have been reported.

3. Colony Population - Colonies of several species of fire ants achieve rapid growth by an emphasis on cooperation, rather than competition, during the founding of a new colony. A number of newly mated queens may share in the excavation of the founding nest and in the rearing of the first brood. This cooperation aids in survival during drought or winter.

   Colonies of red and black imported fire ants become territorial as they grow; they defend a plot against all other fire ants, and sometimes other ants. Therefore, fire ant colony populations will reach an upper limit depending on the territory size of mature colonies. A typical figure for pasture land seems to be about 20-25 mounds per acre (Tschinkel, 1982).

6. Seasonal Abundance:

A. Red Imported Fire Ant - This ant is a tropical ant (imported originally from Brazil) and lacks a true hibernation period. However, there is a seasonal nature to colony life, probably brought on by

seasonal fluctuations of temperature and rainfall in the U.S. Production of reproductives (and therefore the potential for founding of new colonies) has been found to peak in May, June and July in Florida, with the greatest numbers produced in June (Morrill, 1974). Few reproductives are produced between September and March.

B. Black Imported Fire Ant - This ant has its major region of origin in Argentina. No information about seasonal population fluctuations could be found.

C. Southern Fire Ant - Males and females of this native ant have been seen making nuptual flights only in May and June.

D. Fire Ant - See 6.C.

7. Environmental Factors Affecting Survival:

A. Red Imported Fire Ant - The range of the imported fire ant appears to be limited by temperature and moisture. Pimm and Bartell (1980) studied the climatic characteristics of the areas into which the fire ant spread between 1965 and 1976, and noted that the spread was mostly into warmer, drier regions. There was only a small spread into cooler, wetter regions, indicating the northward spread has reached a limit; there was no occupation of cold, dry regions.

Summer rains are necessary for fire ant reproduction (Tschinkel, 1982). Mating flights occur on warm days after rain, so areas with dry summers, such as California, would probably not present suitable habitats.

B. Other Fire Ants - The same factors as presented in 7.A. would probably be important in other fire ant survival in the U.S., except in the case of the Southern fire ant. The reproductive cycle of this ant is not as dependent on rain. It is a major pest in California.

8. Medical Importance:

8.1 Direct Effects:

In infested areas, fire ant stings occur more frequently than bee, wasp, hornet and yellowjacket stings. Multiple stings are common because individual ants can administer several stings. The sting produces an uncomfortable, burning sensation and usually results in the formation of a pustule within 6-24 hours.

The majority of stings are uncomplicated, but secondary infections may occur if the pustule is broken. Severe infections requiring skin grafting or amputation have been known to occur.

Some people experience a generalized allergic reaction to a fire ant sting. The reaction can include hives, swelling, nausea, vomiting and shock. People exhibiting these symptons after being stung by fire ants should be removed to a medical facility immediately; death can occur in hypersensitive people. In a survey of 156 families in Lowndes County, Georgia, 4.5% reported reactions severe enough to require medical attention (Apperson and Adams, 1983).

Individuals who are allergic to fire ant toxins may incur considerable medical costs for desensitization programs and/or hospital costs.

8.2 Indirect Effects:

An important indirect effect of the presence of fire ants is fear of being stung. This may cause anxiety in park visitors and personnel and may reduce utilization of sites where fire ants are present.

9. Natural Enemies:

A. Red Imported Fire Ant - The fire ant is beset by a number of natural enemies in its native South America, but most of these were left behind when the ants were imported into the U.S. Certain fungi and arthropods, especially other ant species, prey on the fire ant in Brazil but their introduction into this country is not anticipated.

Some beetles have been found to infest fire ant colonies, but the numbers of ants they destroy is insignificant (Jouvenaz, 1983).

B. Black imported fire ant - The most important enemy of this ant is the red imported fire ant.

C. Southern fire ant - Preyed upon by the Argentine ant.

D. Fire ant - No reports were found in the literature.

III. FIRE ANT MANAGEMENT

1. Population Monitoring Techniques:

A. Red Imported Fire Ant - Population monitoring for fire ant control generally consists of determining the number of active mounds in a particular unit area. Wilson et al., (1981) have suggested that any mound where at least three ants were observed after mound disturbance should be considered active. Moderately to heavily infested fields may contain 80-600 active mounds per acre while in some areas only a few active mounds per acre may be found.

Another method of estimating ant populations for comparison studies is by collecting ants attracted to baits in a test area. A small piece of hamburger and a small piece of agar containing 40% honey are individually placed on two small pieces of aluminum foil or in small plastic cups. The two baits are placed on the ground, 1-3 feet apart, at each bait station. Bait stations are placed about 10 yards apart (Wojcik, 1975). The number of ants attracted to the baits per unit time is determined.

Fillman et al. (1983) used the shake bucket technique to monitor fire ant populations on cotton plants. The bucket was operated by giving 5 shakes to the upper 6-8 inches of the plant terminal into the bucket. Ants falling into the bucket were counted immediately. The authors claim that results were more consistent than visual count methods.

B. Other Fire Ants - See 1.A.

2. Threshold/ Action Population Levels:

A. Red Imported Fire Ant - The threshold population levels for fire ants will vary according to the sites at which they are found.

Residential and Recreational - Because of their intensive use patterns by humans, few active mounds per acre are tolerated. The presence of one active mound per acre probably would indicate the area was suitable for human use; elimination of the single colony should be easy in most cases. Every effort should be made to correlate fire ant populations observed through

the use of monitoring techniques with complaints received from park visitors and personnel. In this way, a complaint threshold level can be established for each park site.

Agricultural - Mounds built by fire ants in fields often interfere with planting and harvesting operations. Not only is equipment damaged or made inoperable by the presence of mounds, but hand harvesters may refuse to enter fields infested by ants. The number of mounds per acre which can be tolerated will depend on the crop in question and mound size and must be determined by the site operator. For example, in soybean fields, densities of 30-40 mounds per acre can cause yield losses of 15% (Lofgren and Adams, 1981). In pastures and hay fields, bales left on the ground overnight attract fire ants and workers who load bales onto trucks can be stung.

Another serious problem for nursery stock owners and users is that stock from areas that have been quarantined because of the presence of fire ants may not be able to be transported into non-quarantined areas, unless it can be certified as fire ant free.

B. Other Fire Ants - See 2.A.

3. Management Alternatives - Non-chemical:

A number of non-chemical techniques for fire ant control exist, but most have not proven to be very successful.

1. Water - Water has been added to individual mounds, with varying degrees of success reported. Water has also been applied as steam, using a steam generator, usually on a cool day. This technique is cumbersome in the field, especially where large numbers of mounds are involved (G. Hoddenbach, personal communication). The applicator tends to run a high risk of being stung using these techniques. Flooding or controlled burning of fire ant infested areas has not only proved ineffective, but may actually promote the increase of new colonies (Collins, 1982).

2. Mechanical Disturbance - Dragging, or knocking down, mounds can provide some season long control but only if mounds are dragged just before the first hard freeze (Wilson et al., 1981). Mounds are destroyed by pulling a steel I-beam drag, weighing about a ton, behind a tractor across the ant-infested area. Destroying mounds during the warm season will not reduce the number of active mounds; ants quickly rebuild their nests.

3. Biological Control - Among the pathogens which infest fire ants in the United States are several species of microsporidia, among them Burenella dimorpha and Thelohania solenopsae (Jouvenaz, 1983). In laboratory studies, species were infected by feeding ants boiled egg yolk wetted with a suspension of spores.

A number of non-specific enemies of fire ants have been evaluated as biocontrol agents. These include a nematode, Neoaplectana carpocapsae Weiser, bacteria, including Bacillus thuringiensis Berliner, B. sphaericus Meyer and Neide, B. larvae White, B. pulvifaciens Katznelson, Serratia marcescens, Pseudomonas aeruginosa, (Schroeter) Migula, and P. chloraphis (Guignard and Savageau) Bergey et al.; fungi, including Beauveria bassiana (Balsamo) Vuillemin and Metarhizium anisopliae (Metschnikoff) Sorokin; various viruses including baculoviruses and iridescent viruses; and a mite, Pyemotes tritici. The most effective of these is N. carpocapsae; one application (10^6 2nd-stage daurlarvae/mound) can inactivate ca. 80% of treated mounds in 90 days. This nematode can be reared cheaply in artificial media and stored for months; however, its use is limited to single mound treatments, and for this purpose degradable chemical toxicants are more efficacious.

The straw itch mite, P. tritici, can also inactivate fire ant mounds. Bruce and LeCato (1980) reared mites in synchronous culture on insect pupae (cigarette beetle, Lasioderma serricorne) and applied ca. 100 ml of pupae to single mounds as the first progeny emerged from the female mites. Three to 10 applications at about 2-week intervals gave 70% control. Practical use of P. tritici for fire ant control must await the development of more efficient methods of mass production and increased effectiveness. Also, P. tritici is frequently regarded as a pest. Proof must be obtained that this mite can be used without risk to those handling it or to people exposed to it after its dispersal.

At this time it appears that infestation of either N. carpocapsae or P. tritici do not spread to nearby mounds; thus, their use would require treatment of each individual fire ant mound.

4. Public Education - Perhaps the most effective measure which can currently be utilized in preventing injury to park visitors and personnel is education. Visitor activities should be directed away from highly infested areas and visitors should be informed about the habits of the pests. Visitor should be encouraged to use proper sanitation procedures so that fire ants are not attracted to such sites as picnic areas. Information about first aid measures to be taken if a person is stung should be made available.

4. Management Alternatives - Chemical:

Before considering chemical alternatives, the NPS regional IPM coordinator should be consulted to determine which pesticide, if any, should be used in a fire ant control program.

A. Conventional Chemicals - A number of compounds are currently registered for control of imported fire ants, and others are being actively field tested. Among the newer of the registered compounds is the product Amdro which may be broadcast by ground or air to pastures, ranges, lawns, turf and nonagricultural lands. Amdro, in a bait formulated on corn cob grits, can also be applied on a mound by mound basis. Amdro (0.88%) at 0.1-0.2 g per mound is applied; a 90% kill rate has been reported (C.S. Lofgren, personal communication).

Those registered compounds which can be used as mound drenches include chlorpyrifos, diazinon and orthene for lawns and recreation areas. The problems with mound drenches are (1) the difficulty of locating small or hidden mounds (2) the need for multiple applications and (3) the necessity of applying the drench when ants are most susceptible (R.J. Sauer, 1982).

Compounds under active development include EL-468, and avermectin B_1, both applied as a ground or aerial broadcast to non-agricultural lands.

It must be pointed out that the effectiveness of pesticides for fire ant control is a controversial issue. In spite of the use of pesticides, the imported fire ant has increased its range greatly over the last 20 years. Tschinkel (1982) states that "large scale, unspecific control programs aid, rather than hinder, the establishment and spread of the fire ant

and accentuate its dominance over native ants." He points out that before imported fire ants can be managed effectively, more knowledge about the interactions among ants, their environment and chemical agents must be developed.

B. Non-Conventional Chemicals - Research on insect growth regulators for control of fire ants is ongoing. Juvenile hormone mimics, which stop the development of immature ant stages, are under development. One of these, Pro-Drone (MV-678), has been registered. Formulated on a corn cob grit, it is fed to the queen who then produces only reproductives, not workers. It has been reported to give good control of imported fire ants; a 95% reduction of ants in 8 months has been reported (G. Bushman, personnal communication).

The use of pheromones in fire ant control has also been examined, since these chemicals offer ways to upset the behavioral balance in fire ant communities. Behavioral chemicals are important in colony founding, egg laying, brood care, and many other functions. Research indicates that certain behavioral chemicals have the potential of being used to make toxic baits more attractive or more specific for fire ant management.

5. Summary of Management Recommendations:

1. Park visitors and personnel should be directed away from infested areas and encouraged to observe proper sanitation procedures so that fire ants are not attracted to recreational sites.

2. Dragging, or knocking down, mounds just before the first hard freeze, should be examined as a control measure if it is warranted by the situation. Boiling hot water or steam may also be used.

3. Chemical control, using Amdro as an individual mound treatment, may be attempted if other control measures have failed and the use of pesticides has been approved by NPS.

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NATIONAL PARK SERVICE
IPM Information Package

FLEAS

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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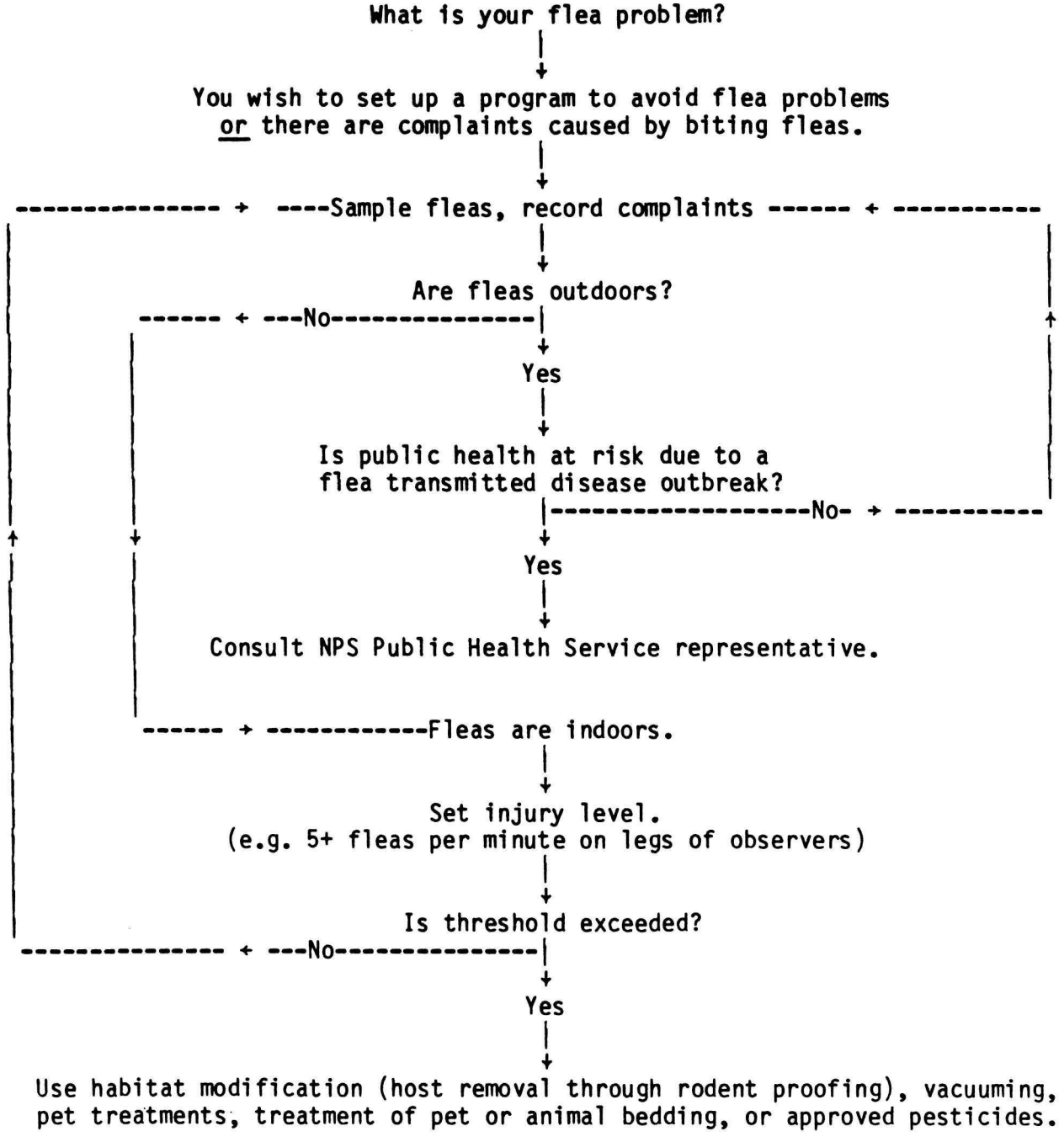
I. FLEA IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to the Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. BIOLOGY AND ECOLOGY OF FLEAS

1. Species Described:

Although there are over 250 species of fleas described in North America (Pratt, 1957), only a few are commonly encountered by humans with enough frequency to be considered pests (Ehman & Story, 1982).

A. Cat Flea - Ctenocephalides felis (Bouche')

B. Dog Flea - C. canis (Curtis)

C. Human Flea - Pulex irritans L.

D. Oriental Rat Flea - Xenopsylla cheopis (Rothschild)

Other species such as the rabbit flea (Cediopsylla symplex [Ba er], mouse flea (Ctenopsyllus segnis [Bosc.]),squirrel flea (Orchopea howardii [Baker]), and the ground squirrel flea (Diamanus montanus [Baker]), may achieve pest status when their host mammals nest in or near structures or the fleas attack hunters and hikers. Some, such as the northern rat flea or ground squirrel flea are important vectors of sylvatic plague and murine typhus.

See page 167-174 of U.S. Department of Health, Education, and Welfare (1967), for pictorial keys to common fleas of the United States.

2. Geographic Distribution:

A. Cat Flea - Abundant in eastern United States and far western U.S. Most common flea on cats and dogs.

B. Dog Flea - Throughout U.S. Same range as cat flea.

C. Human Flea - Most common in mid-West, South, and Pacific Coast

D. Oriental Rat Flea - Common in seaports, associated with Norway and roof rats.

3. Habitat:

Outdoors, fleas are found in mammal and bird nests. Indoors, fleas are often found in pet bedding and in the nests of small mammals behind walls or in other areas.

4. Hosts:

Adult fleas are external parasites of warm blooded animals (mammals and birds). Most species parasitize mammals and prefer one species.

.ife
:ycle:

Females deposit eggs in groups of 1-18 on the host after a blood meal. Some species such as the cat flea can deposit up to 25 eggs per day and over 1000 in a lifetime. Eggs soon drop off or are brushed off. Due to their spherical or oval shape, they roll into cracks and crevices on the floor or in or near nests and bedding. Eggs are whitish, and 0.5 mm in diameter. Eggs hatch in 2-21 days.

Larvae are approximately 1.5 mm when first hatched, white, and have fine hairs. They lack legs or eyes but possess biting mouthparts. Most species feed on dried blood from the host (in the form of adult flea feces) or organic debris present in cracks and crevices. They also feed on cast larval skins. Depending on the availability of food, relative humidity, and other environmental factors, larvae pass through 3 stages (instars) in one week to several months. Optimal conditions for larval development are temperatures of 65°-80°F (18°-27°C) and 50%-92% relative humidity. Larvae pupate within cocoons spun from silk and may be covered with debris.

The pupal stage usually lasts aproximately 1 week. The newly emerged adult may remain in the cocoon for some time, but under adverse conditions, up to a year may be spent in the cocoon. Emergence occurs in response to pressure applied to the cocoon or detection of host warmth, vibrations, or carbon dioxide (CO_2) in the host's breath.

Adult fleas are small, brownish insects flattened from side to side, without wings but with powerful jumping legs. Adults may live for several years and go without feeding for months at a time under extreme conditions. Fleas may remain in a structure long after the host mammals have been removed. Depending on the species and environmental conditions, adults may breed from 2 weeks to 2 years after emerging. Adults feed on blood, and females deposit eggs only after a blood meal. Most species remain on the host only long enough to feed. Nearly all species have host preferences but are not restricted to any one host species. This trait is responsible for the transmission of several diseases from one host species to another (i.e., plague or murine typhus) from rats to humans. Adults prefer warm humid places and will leave a host if it dies.

6. Seasonal Abundance:

Outdoors, fleas are most abundant during humid, rainy summers and are more common outside in the southern U.S. than in the North. Indoors, warmth and high relative humidities are condusive to large populations. The sudden appearance of large numbers of adult fleas in mid summer and fall ("flea seasons") is due in large part to the onset of higher humidities and temperatures which permit larval development to accelerate. Larvae may undergo arrested development in less than favorable conditions.

7. Responses to Environmental Factors:

As noted above, warm humid environments are favored by fleas. Larval fleas are unable to regulate water loss due in part to the thin exoskeleton. Larval mortality is high in areas where humidity is low and temperatures are high. Fleas are seldom pest problems in such areas.

8. Medical Importance:

8.1 Direct Effects:

Flea bites vary in effect from short-lived itching weals to an overall rash, to symptoms which may last over a year, depending on the sensitivity of the victim. Young children are more sensitive than older persons.

Commonly, a small red spot appears where the skin has been pierced. Little swelling ensues, but the spot is accompanied by a red "halo" of irritated skin which usually lasts for several hours to a day.

8.2 Indirect Effects:

Fleas are vectors of several diseases important to human health including plague, murine typhus, and tularemia.

The oriental rat flea is the most important plague vector from rodents (primarily rats) to humans, but at least 30 other flea species can also transmit the disease including the northern rat flea, dog flea, cat flea, and the human flea. Plague (in the sylvatic form) is endemic in the western U.S. among small rodents such as chipmunks and ground squirrels.

Nearly all known cases of plague in humans in the U.S. since 1925 have been associated with wild rodents (mostly from the Rocky Mountain states) and their fleas. An average of 6 cases per year are reported. Periodic epizootic outbreaks occur, resulting in massive mortalities among wild rodents and displacement of disease-carrying fleas to other hosts. The greatest threat to humans will exist when domestic rats are exposed to infection from wild rodents in areas adjacent to human communities.

Murine typhus is a mild form of epidemic typhus which is usually spread by the human louse. The Norway rat population is the main reservoir to the disease. It is most common in the Southwestern and Gulf States, but may be spreading northward. The disease is commonly spread from rat to rat, and from rat to human by the oriental and northern rat fleas. It has also been transmitted by cat fleas from infected feral cats.

Fleas are also vectors of tularemia, a disease related to plague. The natural reservoirs of tularemia are cotton tail rabbits in the East, and jack rabbits in the West. Most cases are from hunters.

Fleas can also be intermediate hosts of several species of tapeworm including species which parasitize humans, dogs, and cats.

9. Natural Enemies:

Fleas are preyed upon by ants and several beetle species which feed on larvae in the hosts' nests (Fox and Bayona, 1968).

III. FLEA MANAGEMENT

1. Population Monitoring Techniques:

Fleas can be monitored in several ways; the simplest is to count and collect fleas landing or crawling on an observer's lower legs for 1 minute. In making surveys, trousers should be tucked into white socks to prevent bites and make collecting easier (socks can be put on over shoes). Light-colored trousers are preferred to provide greater contrast and facilitate counting and collection. A variation on the above is to wrap fly paper (sticky side out) around the lower legs and count fleas adhering after a predetermined interval (Cole & Burden,1978).

Fleas can also be collected by using a light source as an attractant. A light bulb or candle is placed in the center of a square of sticky paper or a bowl of water to which a small amount of detergent (to destroy surface tension) has been added. Fleas attracted to the light are caught on the paper or drowned in the bowl where they can be collected and counted later.

Fleas may also be combed off animals for an index of animal infestation.

An animal may be placed in a plastic or zippered bag with its head outside. Carbon dioxide (CO_2) or insecticide is introduced into the bag. Fleas which fall off the animal are collected as well as fleas which are combed off the animal over a white surface (Ehmann and Storey, 1982).

Pet bedding should be periodically checked for "salt and pepper" (flea eggs and dried-blood feces of adult fleas) which is indicative of infestation. Larvae and pupae can be found at the edge of pet bedding or animal nests.

2. Threshold/ Action Population Level:

In areas where plague is endemic (i.e., Southwestern U.S.) efforts should be made to keep humans and fleas (in this case their wildlife hosts) separate. Camping and other outdoor activities should be restricted especially during an outbreak when fleas seek other hosts. Check with Public Health Service officials if your area is affected.

Indoors, 5 or more fleas on the legs of observers in less than 1 minute is indicative of severe infestation.

In most other cases, fleas are considered pests due to the nuisance caused by their bites.

Decisions on control should be made on a case by case basis.

3. Management Alternatives - Nonchemical:

Fleas require warm blooded hosts to develop and for egg maturation. Elimination of suitable habitat for wild rodents and other animals near structures will often reduce flea population levels. Screening of foundation vents to prevent animals from resting under structures, elimination of vegetation and other rodent harborage, as well as rodent proofing of structures will reduce flea levels.

Indoors, all pet bedding and sleeping areas should be carefully examined for fleas and washed if necessary. Cracks and crevices should be vacuumed and sealed, especially the area between the baseboard and floor. Vacuum cleaner bags should be discarded to prevent reinfestation. If possible, indoor humidity should be lowered to below 50% or as much as possible to kill larvae.

4. Management Alternatives - Chemical:

The following pesticides are registered for use against fleas (Schwartz, 1982):

Silica aerogel
Carbaryl (5% dust)
Precor
Pyrethrins
Resmethrin

Treat floors and baseboards; dust rugs thoroughly, paying particular attention to pet beds and loafing areas. Spray rugs and furniture lightly, vacuum before treatment. Silica aerogel such as Dri-die 67® is often used to treat crawlspaces, wall voids, and attics.

Pets and other animals may be bathed or dusted with a material containing a pesticide or flea repellant. Collars impregnated with insecticides, such as tempephos or dichlorvos which kill or repel fleas, have been used with variable success. Several such materials are commercially available. Fleas on wild mammals have been controlled by placing insecticide in burrows or at bait stations where wild mammals receive a dusting while they are feeding.

Methoprene, an insect growth regulator (IGR) is a synthetic hormone which prevents certain insects from maturing properly, causing lethal complications during pupation.

Methoprene is registered for fleas in two formulations: an aerosol fogger which includes chlorpyrifos as an adulticide; and an emulsifiable concentrate (EC) formulation of methoprene only. It is marketed for use by pest control operators (PCOs) under the trade name Precor®. Methoprene is also available to the general public under the trade name Strike Flea Ender®, and to veterinarians as Vet-Chem Syphatrol-10®. A formulation for use in rodent burrows (in areas where flea-borne disease is endemic) and incorporating an adulticide, is currently being tested.

Methoprene is registered for use in food areas (David Sullivan, Product Manager, Zoecon Corporation, personal communication).

Methoprene does not affect adult fleas or pupae. Effects begin 2 weeks after application when treated larvae begin to pupate. Control is for 3 months or more with each treatment.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Exclude wild mammals and their fleas by rodent proofing all structures.
2. Eliminate harborage for hosts from around structures.
3. Vacuum cracks and crevices especially the areas between baseboards and floors to remove eggs and larvae.
4. Bathe or dust all pets and other domestic animals with commercial flea treatments.
5. Treat floors, rugs, furniture, pet bedding, and baseboards, if necessary, with approved pesticides.

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NATIONAL PARK SERVICE
IPM Information Package

FLIES I
(HOUSE, STABLE, FACE)

Final Report

27 July 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20850

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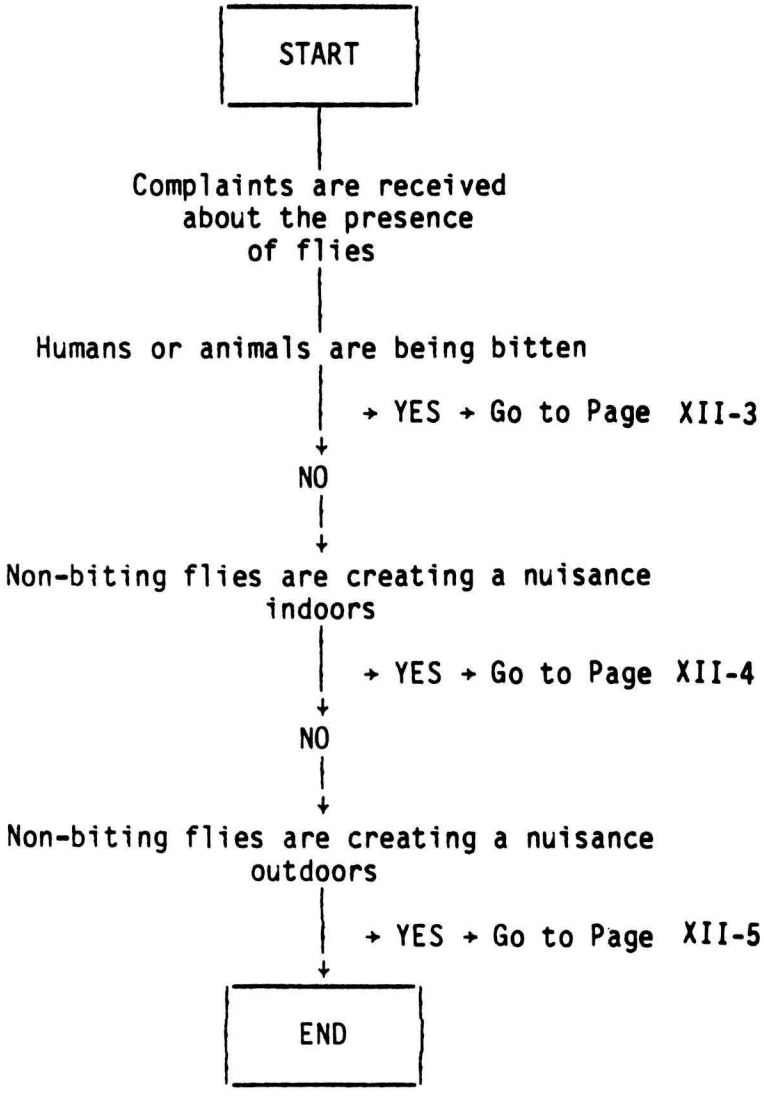
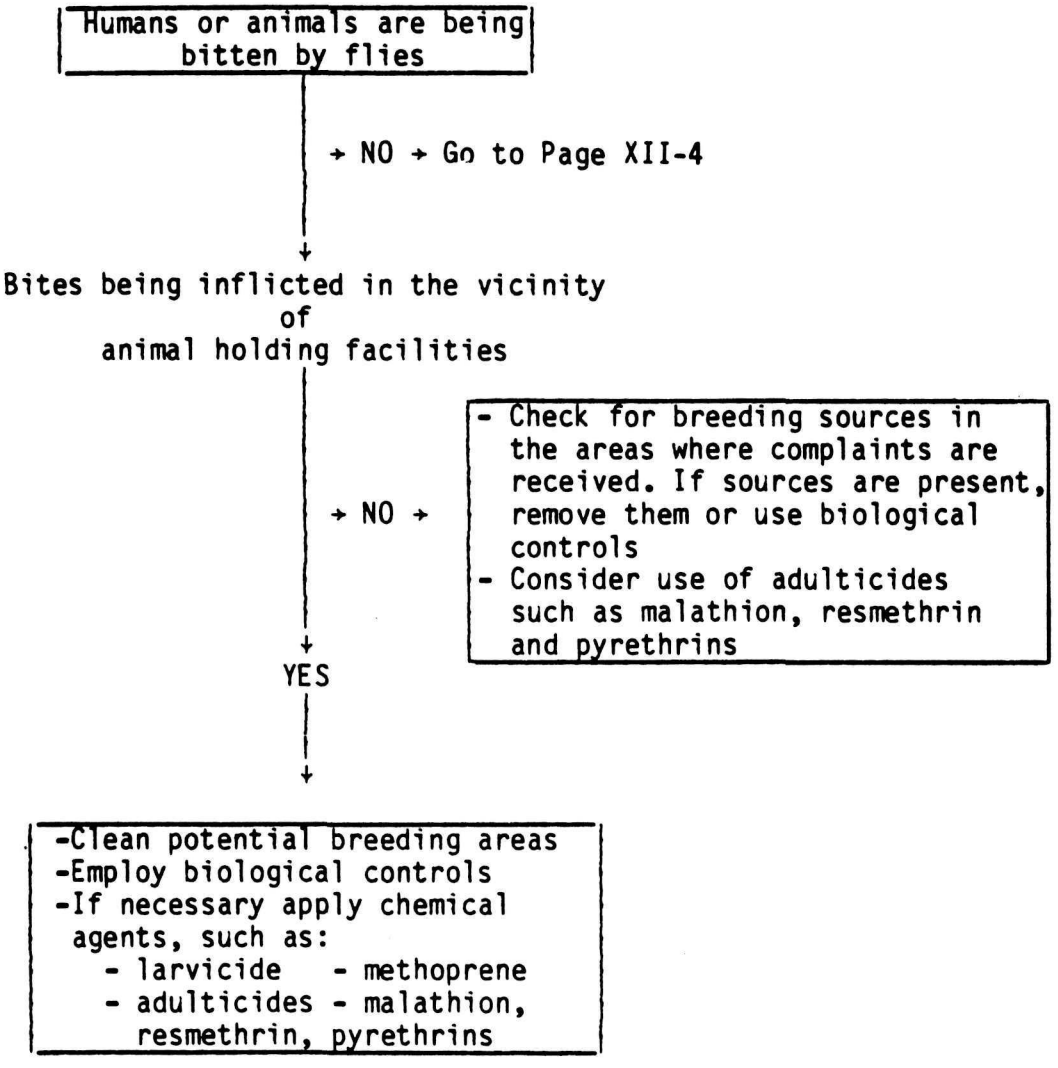
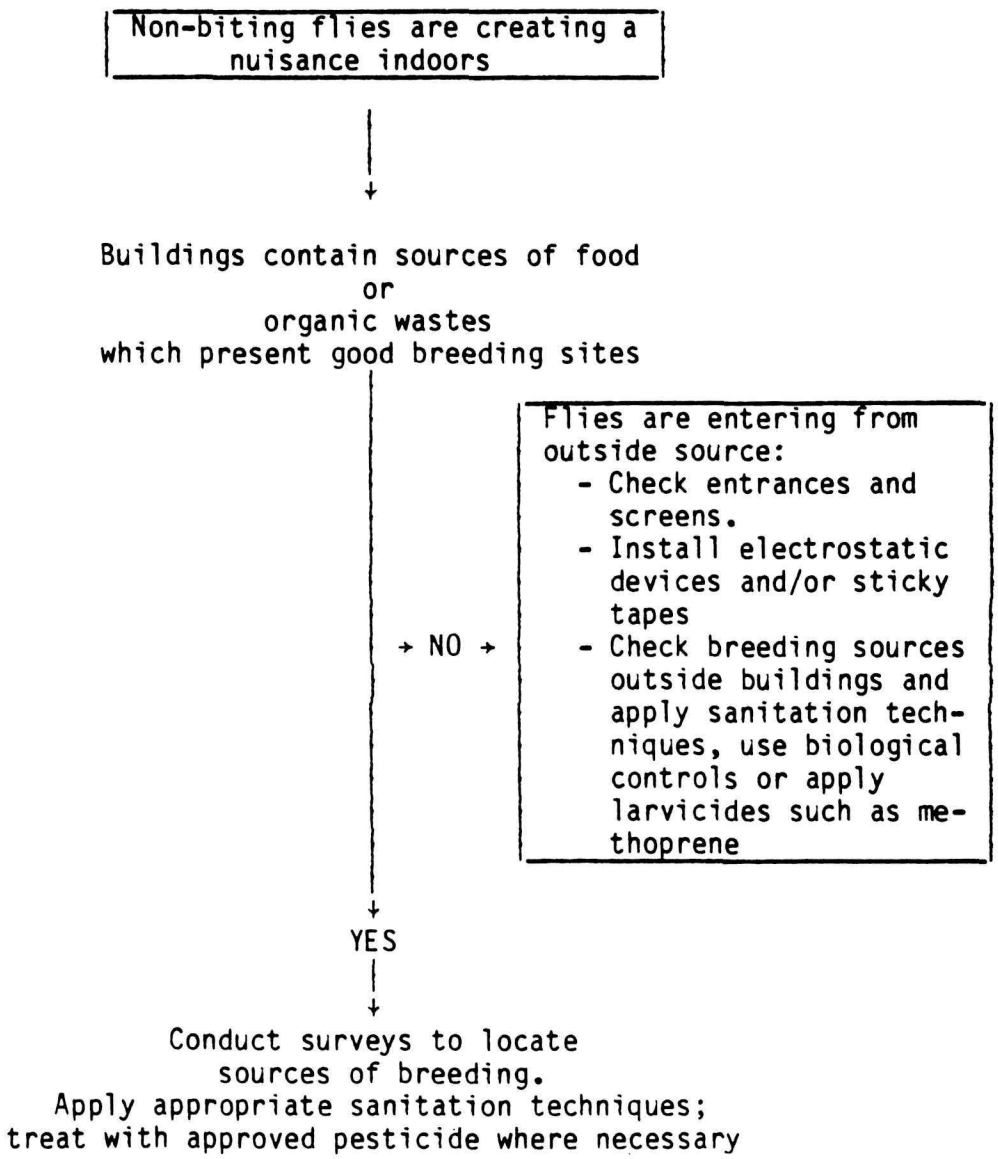
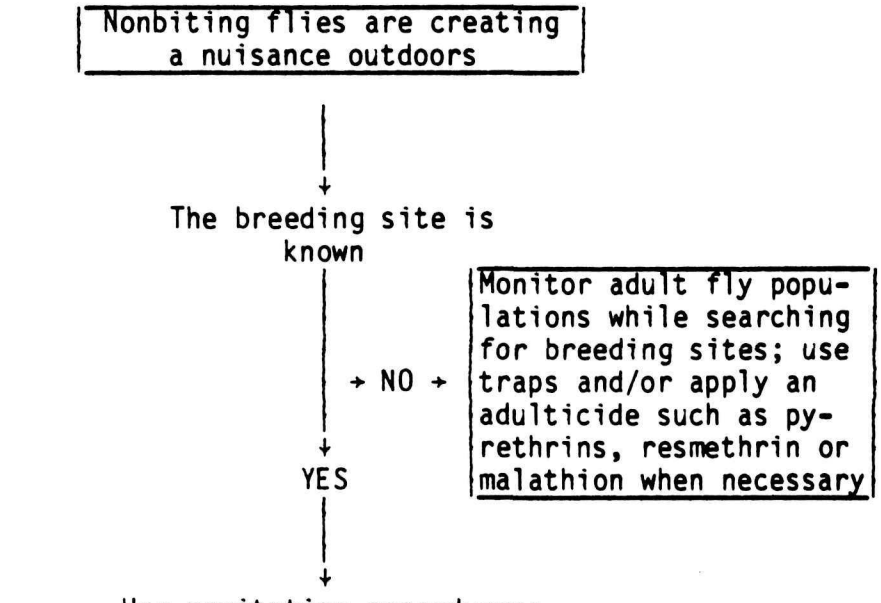
I. FLY IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on annual basis by the Director, NPS.




Humans or animals are being bitten by flies
→ NO → Go to Page XII-4
Bites being inflicted in the vicinity of animal holding facilities
→ NO →
- Check for breeding sources in the areas where complaints are received. If sources are present, remove them or use biological controls
- Consider use of adulticides such as malathion, resmethrin and pyrethrins
YES
-Clean potential breeding areas
-Employ biological controls
-If necessary apply chemical agents, such as:
- larvicide - methoprene
- adulticides - malathion, resmethrin, pyrethrins


Non-biting flies are creating a nuisance indoors
Buildings contain sources of food or organic wastes which present good breeding sites
NO
Flies are entering from outside source:
- Check entrances and screens.
- Install electrostatic devices and/or sticky tapes
- Check breeding sources outside buildings and apply sanitation techniques, use biological controls or apply larvicides such as methoprene
YES
Conduct surveys to locate sources of breeding.
Apply appropriate sanitation techniques; treat with approved pesticide where necessary


Nonbiting flies are creating a nuisance outdoors
The breeding site is known
NO
Monitor adult fly populations while searching for breeding sites; use traps and/or apply an adulticide such as pyrethrins, resmethrin or malathion when necessary
YES
Use sanitation procedures; use biological controls or larvicide such as methoprene, if necessary

II. BIOLOGY AND ECOLOGY OF FLIES

1. Species Described:

   A. House fly - Musca domestica L.

   B. Stable fly - Stomoxys calcitrans L.

   C. Face fly - Musca autumnalis DeG.

   See page 122 of U.S. Department of Health, Education and Welfare (1967) for a comparative key to various fly species.

2. Geographic Distribution:

   A. House fly - Widely distributed throughout the United States.

   B. Stable fly - Widely distributed throughout the U.S.

   C. Face fly - The only states free of the face fly are Texas, Louisiana, Florida, New Mexico, and Arizona.

3. Habitat:

   A. House fly - House flies may be found in any situation where sources of organic wastes are available. This includes landfills, garbage dumps, barns, etc.

   B. Stable fly - Stable flies may be found near livestock or fermenting vegetable matter such as straw, seaweed, grass clippings, etc.

   C. Face fly - Females may be found near livestock or livestock droppings. Males feed on nectar of flowers and may be found in pasture margins, wooded areas at pasture edges and fence rows.

4. Hosts:

   A. House fly - House flies feed on decaying organic matter. They may be found around manure piles and rotting garbage. They are not blood feeders.

   B. Stable fly - Adult stable flies are blood feeders They generally feed on the lower part of the legs of cattle and horses. They may also feed on humans and dogs. Flies only stay on the animal long enough to obtain a blood meal and then seek a shaded place such as a fence or barn wall to digest the meal. They return for additional meals several times a day, but most activity takes place between 7-8 am and 6-7 pm.

C. Face fly - Adult face flies do not have mouth parts capable of piercing the skin of their hosts, so they are not normally blood feeders. Females cause annoyance while feeding on wounds or moist mucus secretions on an animal's face. As noted above, males are nectar feeders and are not attracted to animal secretions.

5. Life Cycle:

A. House fly - The female house fly deposits many eggs in decaying organic matter, such as manure piles and decaying garbage. A female deposits from 100-150 eggs at a time; the eggs hatch under summer conditions in 12-24 hours. The larva develops rapidly and becomes a pupa (nonactive stage) in 15 days, then becomes an adult in 2-4 days. Within 2 days after emerging, adults can mate and 2-3 days after mating, the female can lay eggs. House flies generally overwinter as immature forms or, less commonly, as adults.

B. Stable fly - The female stable fly generally deposits her eggs in decaying organic matter, such as hay or straw. Eggs hatch within 1-4 days and the larvae bury themselves, begin to feed, and mature to adults in 14-26 days. Stable flies can mate several days after maturation. They generally overwinter as immature forms buried deep in straw or manure piles.

C. Face fly - Females lay eggs only in fresh manure; larval development occurs within the manure and in the soil surrounding it. The total cycle from egg to adult takes 8-25 days. Face flies overwinter as adults in barns, buildings or under tree bark.

6. Seasonal Abundance:

A. House fly - House flies can be a nuisance throughout the year. Breeding can take place as long as temperatures are warm enough for flies to be active. Three to seven days of freezing will kill the immature stages. Adult flies are active throughout the winter on warm days and apparently do not hibernate.

B. Stable fly - Stable flies are active during the warm months and are usually found from March to November in temperate zones.

C. Face fly - Face flies are present on cattle and horses from April through October and are present in greatest numbers from July to September.

7. Environmental Factors Affecting Survival:

A. House fly - House flies are sensitive to extremes in temperature and humidity. Low humidity and/or high temperatures affect dispersal rates and cause buildup of high populations at major breeding sites. Low humidity may limit ovipositing females to one batch of eggs.

B. Stable fly - Stable flies prefer humid areas with moderate temperatures.

C. Face fly - Face flies prefer high humidity and moderate temperatures.

8. Medical Importance:

Flies affect the well-being of man and other animals most significantly by transmitting disease causing organisms. Many of the intestinal diseases of humans are transmitted by flies. Filth inhabiting flies have been implicated as carriers of typhoid fever, dysentery, trachoma, tularemia, cholera, tuberculosis, anthrax, trypanosomiasis, leishmaniasis, diptheria, poliomyelitis and a number of other diseases. In most cases the disease-causing relationship is based on the fact that individual flies will explore large varieties of organic substrates and will move contaminants from one site to another. Various species of flies have been implicated in the transmission of food poisoning organisms such as Staphylococcus, Salmonella, and Streptococcus. House and stable flies have been implicated in the transmission of several diseases such as mastitis and infectious anemia in livestock, and face flies have been shown to transmit pinkeye in cattle and horses.

Flies can also cause severe annoyance to people and other animals. Stable flies, for example, are vicious biters and may account for serious blood loss in domestic animals. It has been demonstrated that cattle can lose between 1/4 and 3/4 of a pound per day as the result of attacks by biting flies (Campbell and Hermanussen, 1971).

9. Natural Enemies:

Flies have many natural enemies ranging from insects to birds. These enemies can attack all stages of the life cycle from egg to adult. Many of these natural enemies can be used to provide biological control (see Section III.3).

III. FLY MANAGEMENT

1. Population Monitoring: Techniques:

Population monitoring is an important part of any fly management program. While thresholds for treatment must be determined for an individual situation (see Section III.2), monitoring programs serve as valuable tools for treatment decisions. A sample fly monitoring form is presented on page XII-20

A. House fly - House flies may be difficult to monitor effectively. However, many trapping methods have been used with some success.

1. Monitoring larvae - Larvae are most often found in decaying animal and vegetable matter. They are commonly found indoors in decaying litter or bedding and outdoors in garbage or manure piles. Among the techniques used for estimating larval populations are: (1) taking a large spoonful of manure from 10 locations in a manure pile, spreading each on a plywood board and counting larvae (Bailey et al., 1970) and (2) placing a known volume of manure in a bucket and collecting pupae by flotation (Hurd et al., 1979).

2. Monitoring adults - The adult house fly can be monitored by several methods, depending on the location. In buildings, sticky fly tapes can be hung from ceilings over areas frequented by flies. However, the usefulness of these tapes is limited because the tape may lose its effectiveness in 1-2 days. In outdoor situations the tapes soon dry out. Some workers have used paper plates smeared with adhesive for trapping flies. Some workers estimate fly populations using a Scudder grill; this grill, 1 m^2, is placed on the ground and the number of flies landing on it in a specified time period, such as ten minutes, is counted and recorded.

   If electricity is available, a fly trap with a UV lamp can be an effective monitoring device. An inexpensive, low maintenance UV lamp has been described by Thimijan et al., 1970; it is constructed of plywood, aluminum screenings, and a bulb. The lamp is sensitive to small changes in populations and captured flies remain in excellent condition for identification. Two traps per medium sized enclosure (e.g. 3,000 ft^2) should be sufficient.

Baited fly traps can also be used as a monitoring device. The Dodge trap (Morgan and Pickens, 1978) is easy to construct; it consists of a carton, a screen cone and a bait source. Flies are drawn to the organic bait and become trapped in the carton. They may be counted on a daily or weekly basis.

B. Stable fly - The techniques described above may also be used to estimate stable fly populations. Another technique described for adults of these insects is a trap consisting of two fiberglass (Alsynite) panels (28 x 45 cm) that are interlocked at right angles and mounted 50 cm above the ground on a stake (Williams, 1973). The panels are treated with an adhesive material. The trap has been highly effective in density assessments when positioned in fly-ways, breeding areas and resting sites.

Treatments for stable fly control have been assessed by counting the number of flies present on a "bait" animal for a given length of time. However, the time of day when observations are made is very important because most feeding activity by stable flies occurs at 7-8 am and 6-7 pm.

C. Face fly - A modification of the stable fly trap may be used to estimate face fly populations. A 4-sided fiberglass diamond, painted white and coated with adhesive, is hung from the barn ceiling where it attracts face flies.

Another technique for estimating face fly populations is counting the number of flies found on the faces of several animals per specified unit of time (such as the number of flies/5 minutes).

2. <u>Threshold/Action Population Levels:</u>

Thresholds for fly control treatments will vary with the situation. Every effort should be made to correlate fly populations observed through the use of monitoring techniques with complaints received from park visitors and personnel. In this way, a complaint threshold level can be established for each park site.

A. House fly - When sticky traps were used as monitoring devices, Morgan and Pickens (1978) reported that 50-75 flies/trap/day indicated a moderately heavy population. With UV light traps, collection of 150-200 flies/trap/night indicated a heavy population and with baited traps, 300-400 flies/trap/day indicated a heavy population.

B. Stable fly - The number of flies feeding on a particular animal has not been correlated with the total population of flies at a particular site. However, Morgan and Pickens (1978) suggest that each fly found on an animal during peak feeding periods probably represents 50 flies in the total population. The annoyance factor at the site is the most critical indicator for treatment.

C. Face fly - Since the face fly is not as responsive to baited or light traps as other flies, visual counts are recommended. More than 10 flies per animal face per 5 minutes is an indication of a heavy population (Morgan and Pickens, 1978).

3. Management Alternatives-Non-chemical:

A. House fly

1. Habitat modification - Basic sanitation requires the most effort in terms of manpower but is the most effective way of dealing with pest flies. Breeding places for flies should be eliminated as a first step. Garbage in buildings and recreation areas should be properly stored. Containers with tightly fitting lids should be used for storing food wastes and the containers should be thoroughly cleaned when the food and other garbage is removed. Waste waters from cleaning processes should be channeled into sewers rather than being permitted to run into the ground. Garbage should be properly disposed in an approved sanitary landfill.

For stables and other animal holding facilities, special precautions should be taken. Since manure is a preferred medium for fly egg deposition, these areas should be cleaned frequently and residues discarded in a sanitary manner. Manure turning or spreading aids in drying manure piles and discourages egg deposition. Paved animal runs should drain into sanitary sewers.

To keep adult flies from entering residences, recreation buildings, and food handling establishments, all doors and windows should be supplied with closely fitting screens. These should be routinely inspected for rips or tears. The screens may be supplemented by air screens at entrances, sticky fly tapes or fly traps for more effective control.

Devices which will kill some flying insects, including flies, are manufactured by several companies. Insects are attacted to an ultraviolet bulb which is surrounded by a screen with an electric charge. When the fly contacts the screen, it is killed and its remains drop into an area accessible for easy cleaning.

2. Biological control - A number of parasites may be used to lower the density of fly populations at a given site. The parasites most effective are species of Spalangia and Muscidifurax. These wasp parasites feed and reproduce on immature flies and destroy them. The parasites are harmless to humans and most other insects.

   Commercial insectaries, such as Agricultural Insect Management in Grady, AL, sell these parasites for fly control. The number and species of parasites which should be released varies with the site and situation. Instructions from the supplier of the parasites should be consulted for details. Mass releases are often quite effective when fly populations are high; they may have little effect when densities are low.

   A number of mites have been shown to be predaceous on house flies. Macrocheles muscaedomestica (Scopoli) and Fuscuropoda vegetans (De Geer) attack the eggs and larvae of houseflies and little house flies. Wicht and Rodriguez (1970) investigated the use of predatory mites, a larvicide that would be harmless to mites,and a poison bait for adult houseflies. Fly populations were reduced to approximately 35% of their pretreatment level in 3 weeks.

3. Sterility induction programs - Chemosterilants have been investigated for a number of years as a means of fly control. Many chemicals have been examined for their ability to sterilize male flies. Pausch (1971, 1972) tested the chemosterilant activity of six substances: apholate, hempa, metepa, tepa, tetramine, and triphenyltin hydroxide.

   In laboratory tests, hempa, metepa, and tepa induced a high degree of sterility in flies after exposure for 3 days to the chemosterilants. Fly populations in an enclosed barn showed sterility levels of >80% after 4 weeks of exposure to chemosterilants. In 7 weeks the population was so low that few flies could be captured.

   While a number of these types of sterility induction programs have been carried out experimentally, the technique has not yet proven to be effective in practical situations.

B. Stable fly - Those control measures listed for house flies can also be effective in controlling stable flies. In addition, laboratory tests have shown that the stable fly is suceptible to the pathogen Bacillus thuringiensis, although levels needed for control are high.

C. Face fly - See 3.A. for management techniques. The face fly may also be infested by a nematode Heterotylenchus autumnalis which effectively makes the female incapable of laying eggs. Some attempts at rearing and releasing the nematode have been made but much work remains to be done in this area.

4. Management Alternatives - Chemical:

A. House fly

While several chemicals for fly control are mentioned in the following sections, the NPS Regional IPM Coordinator should be consulted to determine which pesticide, if any, is best suited for a particular fly control problem.

1. Larvicides - Larvicides, such as malathion, dimethoate or dichlorvos, are employed less frequently than adulticides for fly control since breeding sites are often far from the "damage site" and may be more difficult to treat. The high organic content of larval sites reduces the effectiveness of some pesticides, and larviciding also encourages the accelerated development of insecticide resistence. In a study investigating fly control in poultry houses (Axtell, 1970b), 16 to 18 applications of pesticides were needed during the course of the season for satisfactory fly control. Manure inhabiting mites, which prey on larvae, were destroyed in the course of larviciding.

Insect growth regulators (IGR's) such as methoprene do not kill fly larvae but prevent them from developing into adults. IGR's are applied to filth sources where eggs would be expected to be laid. IGR's can be very effective as a component of a total larval control program.

2. Adulticides

a. For control of adult flies within buildings, insecticide emulsions or suspensions may be applied to exterior surfaces on which flies rest. Compounds such as pyrethrins and resmethrin are commonly applied to run-

off. In outdoor situations where appearance is not a critical factor, the addition of 1 lb of sugar/gal attracts flies and increases the effectiveness of the treatment. Treatments are only temporarily effective because of the low residual activity of these compounds.

b. Space sprays with resmethrins or pyrethrins may be used for spot treatment inside buildings, but frequent retreatment is necessary. They are even less effective outdoors and must be repeated at least daily where flies are a problem.

c. Adults may also be controlled by means of poison baits. A bait of sugar and molasses, to which toxicant is added, was once widely used but it has been replaced by fermenting protein baits. The baits contain yeast hydrolysate or corn protein with malathion, dichlorvos, diazinon or naled as the toxicant (Metcalf and Flint, 1962). Bait stations must be cleaned frequently, usually once per week, or the contents can become so heavily clogged with dead flies that contact with the bait is impossible (Anon., 1971).

d. Slow release plastic formulations of pestides have been used experimentally. Bailey et al., (1971) applied several pesticides formulated in resins which were then ground to powders or beads and applied to the floors of barns. Three applications of slow release formulation of dichlorvos controlled adults for about 7 weeks. Bennett and Runstrom (1979) showed that encapsulated resmethrin formulations were effective in controlling houseflies even after 3 months.

Hanging fiberglass strips have been shown to be attractive to house flies. When permethrin-treated strips, suspended by cords, were used in swine and calf barns, house fly populations were reduced by 75%.

B. Stable fly - A number of chemicals are used for control of stable flies including pyrethrins, resmethrin and malathion. As noted above for house flies, both larvicides and adulticides may be used. Sprays have been applied directly to animals in some studies but these lost effectiveness in relatively short periods of time.

Attractants may also be used in combination with pesticides for stable fly control. Williams (1973) designed a trap for survey studies which was made of fiberglass panels (coated with an adhesive) which appeared to be attractive to stable flies. Meifert et al. (1978) coated non-sticky panels with permethrin and found that the units removed more than 30% of the stable flies in a cattle yard when they were used at a rate of 1 unit/5 animals.

C. Face fly - See Section 4.A.

5. Summary of Management Recommendations:

A. House fly - Site management is a very important aspect of fly control. Breeding sites should be eliminated by properly disposing of animal wastes and garbage. Containers for food wastes should be tightly closed and cleaned frequently. Moisture control for waste containers (i.e. proper drains for dumpsters) should be carefully observed. Wastewater from food establishments and stables should be channeled into sewers, rather than be allowed to run into the ground. Appropriate approved landfill practices should be observed.

Doors and windows of buildings should be tightly screened and fly traps and/or sticky tapes used where they would be useful. Electrostatic insect killing devices should be used where appropriate. Air screens at loading entrances, especially in warehouses and food handling establishments, should be investigated.

Fly populations should be monitored to determine when nonchemical or chemical treatment may be necessary. Correlating population densities with complaints from park visitors and personnel is essential.

Biological controls should be used when appropriate. Release of larval parasites alone or in conjunction with fly larvicides, adulticides or traps should be investigated as a control measure in areas where fly breeding is a problem.

Conventional chemical controls may be used when other methods are not effective. When considering this alternative, breeding sites should be identified and registered larvicides should be used only when necessary. Care should be taken to use pesticides so

that development of resistance is not encouraged. This involves use of pesticides as infrequently as possible and also requires frequent rotation of products. Those pesticides least harmful to mites and non-target insects should be used. Consult with NPS pest management staff to determine which pesticide, if any, is best suited for your fly management program.

B. Stable fly - See 5.A. House fly.

C. Face fly - See 5.A. House fly.

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V. SAMPLE FLY MONITORING FORM

Date:_____ Area:_____ Recorded by:_____

Sketch map of survey area:

N
W--|--E
S

- Indicate type of survey conducted:
  ___ Trapping
  ___ Observation
  ___ Other
- Indicate trap locations, if appropriate
- Include any areas considered especially important such as landfills, kennels, stables, etc.

Survey results:

1. Details of method (type of observation, time of observation, etc.)

2. Fly count:

   Species #/_____(time)

3. Proposed treatment

4. Date treated _____ Treated by:_____

5. Comments

NATIONAL PARK SERVICE
IPM Information Package

FLIES: BITING
(BLACK FLIES AND TABANIDS)

Final Report

1 March 1985

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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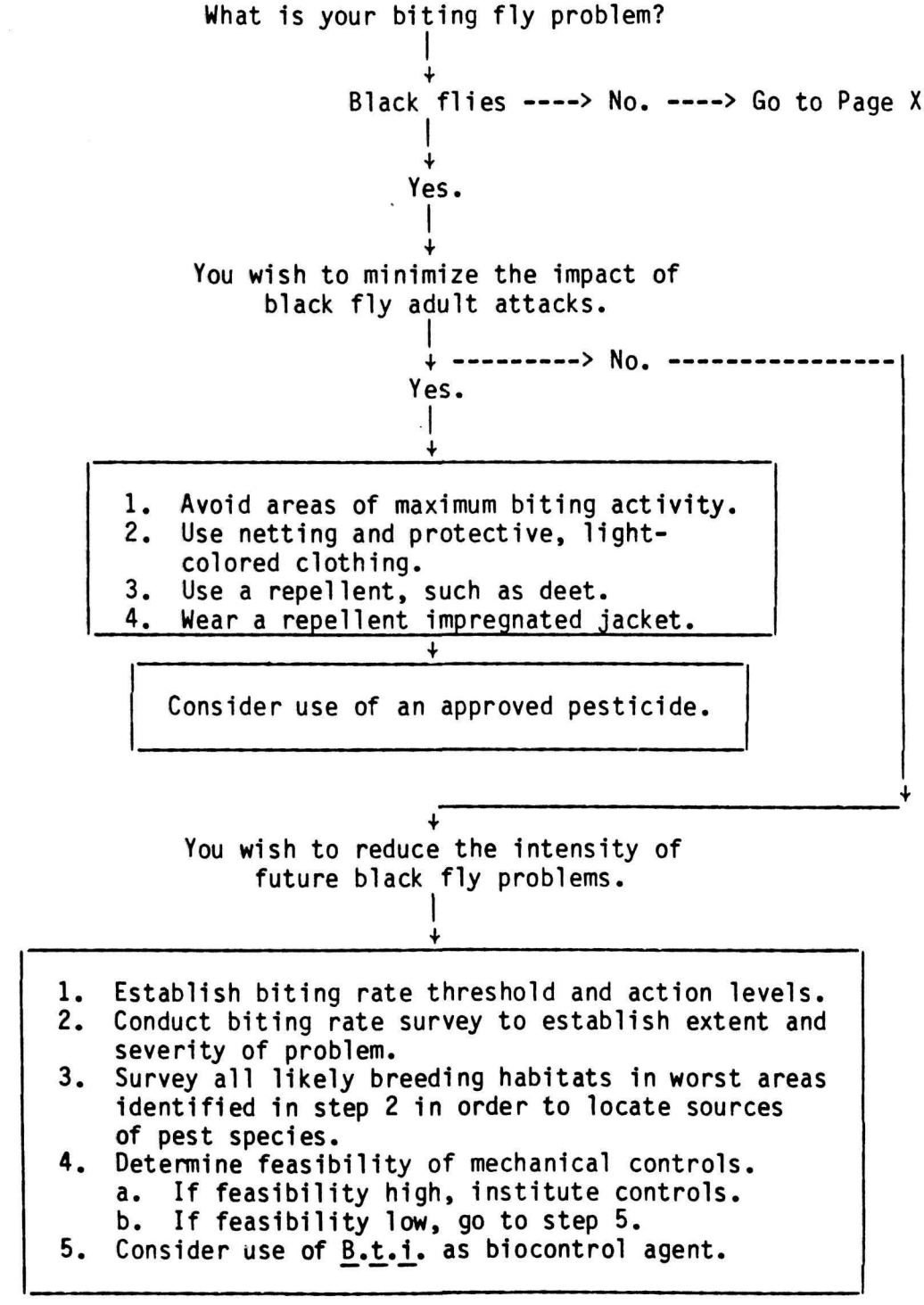
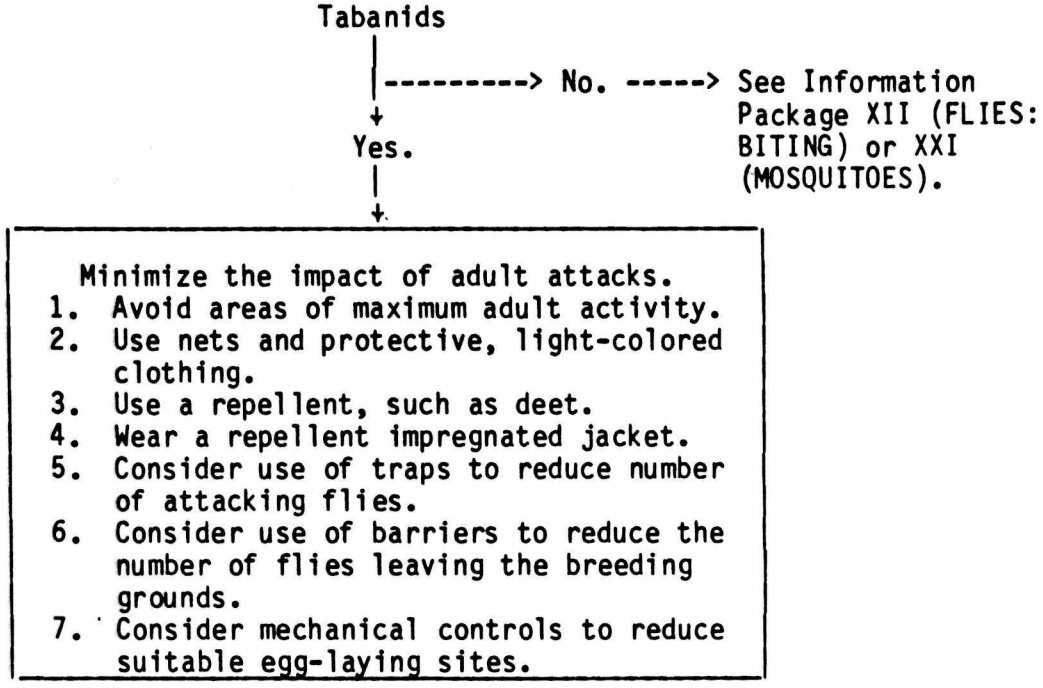
I. BLACK FLIES & TABANIDS IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




Tabanids
No.
See Information Package XII (FLIES: BITING) or XXI (MOSQUITOES).
Yes.
Minimize the impact of adult attacks.
1. Avoid areas of maximum adult activity.
2. Use nets and protective, light-colored clothing.
3. Use a repellent, such as deet.
4. Wear a repellent impregnated jacket.
5. Consider use of traps to reduce number of attacking flies.
6. Consider use of barriers to reduce the number of flies leaving the breeding grounds.
7. Consider mechanical controls to reduce suitable egg-laying sites.

II. BLACK FLIES & TABANIDS BIOLOGY AND ECOLOGY

1. Species Described:

A. Black flies - These blood-sucking flies are members of the family Simuliidae. They also are known by several other common names, including buffalo gnats, humpbacked flies, turkey gnats, black gnats, ear flies, sand flies, and cholera gnats. There are about 150-200 species of black flies presently recognized in North America, but identification is difficult, and many "species" are known to exist in several distinct populations that can be distinguished only on the basis of their chromosome banding patterns (Rothfels 1979). The adults are small, 1-5 mm (1/64 - 3/16 inch) long, and have short, thick antennae with 9-11 segments. The legs are short, and the body is stout and appears humpbacked. The wings are broad and characterized by the strong development of the anterior veins and the weak posterior veins. The eyes of the males are large, nearly meeting along the top of the head, while those of the females are smaller and widely separated. Many species are black or very dark colored, as their name suggests, but others have distinctive light markings, and some are predominately yellow. The females have piercing-sucking mouthparts adapted for sucking blood; the males have sponging mouthparts and do not suck blood. The pupae are short and stout, with the posterior end strongly tapered, and with a pair of filamentous gills at the anterior end. The pupae of most species are enclosed in a slipper-shaped cocoon or irregular case. Larvae are club-shaped, with the head slightly narrower than the rest of the body and the end of the abdomen enlarged. Larvae are white, light or dark green, reddish, gray, or black, with stripes or spots on the head or abdomen of some species. The head is well-defined and, in the majority of species, possesses a pair of distinctive cephalic fans, which are specially modified food-gathering organs. These consist of long, hooked filaments attached to moveable stalks at the sides of the head near the mandibles (jaws). Just behind the head capsule on the underside is a single proleg, or false foot. Black fly eggs are whitish to light orange when first laid, becoming darker as they mature. They are more or less triangular

in outline, ranging from 0.2 to 0.4 mm in length.

B. Tabanids - These flies are members of the family Tabanidae. They include those species commonly known as horse flies, deer flies, clegs, greenheads, breeze flies, gadflies, strawberry flies, and mango flies, and, in some areas, as May flies. There are about 325 species in North America, although some sibling species (pairs of species so similar that they can only be distinguished by experts using special techniques) are known and others are suspected (Sofield et al. 1984a & b). Over half of the species in North America, including most of the pest species, occur in two genera, Tabanus (horse flies) and Chrysops (deer flies). Adult tabanids are medium-sized to large flies with robust bodies. The females have biting mouth parts and the eyes are completely separated; the males have non-biting mouth parts and the eyes usually meet along the top of the head. The adults of species of Tabanus range from 6-30 mm (1/4 to 1 3/16 inch) in length. The third segment of the antenna has a toothlike process near the base, and the last pair of legs lacks long moveable spines (spurs). The eyes of certain species, the greenheads, are bright green, while those of others are dull and dark. The body coloration ranges from black to yellowish brown. The wings are usually hyaline (transparent and glassy), uniformly dark colored, or with a small spot or streak of color. The adults of species of Chrysops are smaller than most adults of Tabanus, most of them being slightly larger than a house fly. The third segment of the antenna is cylindrical and lacks a toothlike process near the base, and the last pair of legs has a pair of moveable spines (spurs) on the tibiae. The eyes of most species are bright green and gold with dark markings, but the colors quickly fade after death. The body usually is brown or black. The wings usually are strongly marked with a dark band along the front edge and one or two triangular bands or streaks extending backward from the front edge in the apical half of the wing. Adults of species in other genera are similar, but differ in coloration and patterning, and details of the antennae, spurs, and other features.

The pupae are shorter than the mature larvae of the same species, and have the anterior end rounded and the posterior end tapered. The head has two tiny tubercles (bumps) that bear 1 (Tabanus and others) or 2 (Chrysops) setae. Most of the abdominal segments have a complete row of spines encircling the segment near the posterior third, and the end of the pupa consists of three pairs of sharply pointed tubercles. Pupae range in color from pale beige to almost black.

The larvae of tabanids range in length from 11 to 50 mm (7/16 to 2 inches). The body is slender, cylindrical, and tapers to a point at both ends, and consists of 12 segments and a terminal breathing tube. The head is small, elongate, and retractile, and has two strong, curved hooks for feeding. Most of the abdominal segments have 3 (Chrysops) or 4 (Tabanus and others) pairs of swellings arranged in a row around the anterior end of the segment; these swellings are used in movement and may have spines or hooks to aid in locomotion. Most species are whitish, yellowish, or greenish, and some are deeply pigmented in a definite pattern.

References for the identification of black flies and tabanids are given in the Bibliography.

2. Geographic Distribution:

A. Black flies - These flies are found throughout the world, but are most abundant in mountainous areas and in the north temperate and subarctic zones.

B. Tabanids - Like black flies, tabanids are found throughout the world. They are most common in areas near water, such as marshes.

3. Habitat:

A. Black flies - The immature stages of these insects are restricted to flowing fresh water. Most species can live only in fast, clean, well-aerated water with suitable solid substrate on which to attach. Some species can live in temporary streams that dry up in the summer months. The adults are strong fliers and may travel a considerable distance from the flowing water of their origin, but they must return to flowing water to oviposit.

B. Tabanids - Larval habitats of tabanids are varied, but most species are aquatic or at least require very moist soil. Most larvae are found at the edges of ponds or streams with exposed loamy soil above the waterline, or in the rich organic substrate of bogs. Some species are well adapted to life in the soil of salt marshes, and the larvae of some species apparently are entirely terrestrial, living in soil where standing water rarely, if ever, occurs. Some species live in tree holes and others live in rotting logs or decaying leaf litter. Adults prefer open areas such as marshes, along the border between forests and pastures or meadows, roadways and rights-of-way, and along paths.

4. Hosts:

A. Black flies - Most females of blood-sucking species have definite host preferences. Some are ornithophilic ("bird-loving"), such as Simulium anatinum (Wood) and S. euryadminiculum Davies, which feed almost exclusively on ducks, and S. slossonae Dyar and Shannon and S. meridionale Riley, which feed on turkeys and other fowl. Certain species feed on mammals but rarely bother humans, such as Simulium arcticum Malloch. The most important pest species of people is Simulium venustum Say, the notorious "white-stocking fly" of the North. Other species feeding on humans are usually of more local importance, although some of them have broad distributions. A few species do not feed as adults, or feed only on nectar.

B. Tabanids - Horse flies and deer flies have been reported feeding on a wide variety of mammal species, as well as on several species of reptiles. There are no records of tabanids feeding on birds. Certain species of horse flies are important pests of livestock animals, but only rarely attack people; for example, Tabanus stygius Say and T. sulcifrons Macquart. Other species attack both humans and livestock and are equally annoying to both. The most important pests of people include: Tabanus atratus Fabricius, the black horse fly (and probably the "blue-tailed fly" of the song); T. quinquevittatus Weidemann, the greenhead; and T. nigrovittatus Macquart, the salt marsh

greenhead. Deer flies feed on a variety of animals, including humans, but are rarely pests of livestock. Species in certain other genera, including Haematopota, Hybomitra, and Silvius, also are important pests of people and livestock.

5. Life Cycles:

A. Black flies - Larvae are found only in swiftly flowing water. To avoid being swept away and still be able to feed, they anchor themselves firmly to stable rocks, sticks, or plants in areas with strong currents, such as riffle sections of streams and the outlets of lakes, beaver ponds, and man-made reservoirs. The larva spins a pad of silk on the surface of the substrate, then attaches itself to it facing upstream, by means of a series of hooks on the abdomen. In this position, the larva leans back with its cephalic fans reaching into the current, regularly folding them to its mouth to eat the particles trapped there. In this way, the larva can feed on very tiny particles carried by the current, including bacteria (Fredeen 1964) and colloidial particles (Wotton 1976). A small number of species feed by grazing algae and bacteria from the surface of rocks. Larvae pass through 5-8 molts prior to pupation. For pupation, the larvae weave a cocoon of silk attached to the substrate. The cocoon may be a crude, coarsely woven mass, or more expertly woven and carefully made, and is often characteristic of the species. The cocoon is slipper-shaped, with the "toe" pointed upstream and the head of the pupa pointed downstream with its respiratory filaments trailing in the current. The pupal period lasts 2-21 days, depending on the species. After emerging, the adults swim or float to the surface and head to the shore to rest among the vegetation while they harden, and may feed on nectar while there. Mating occurs soon thereafter. Males of many species form mating swarms which the females seek out. After mating, depending on the species, the females go in search of their first blood meal. Some species do not take a blood meal at this time, but lay one batch of eggs first, then search for a blood meal, while others can not produce eggs without blood. A few species do not require blood at all, and in fact, the mouth parts of these species are reduced and

incapable of piercing a vertebrate skin. After a blood meal a female rests for 3-8 days while the blood digests and her eggs develop. Egg laying usually takes place near sunset, but may occur at other times. Females of some species fly over the water and tap their abdomen to the surface to release one or more eggs at a time. Other species land on plants or rocks in the water and lay their eggs at the water's edge, or under the water, attached to the substrate. Most females lay 200-500 eggs apiece, but as many as 800 have been counted from a single specimen. The eggs may hatch within a few days or may not hatch for several months, again depending on the species and the time of the year. Some species are univoltine, producing just one generation per year; others are multivoltine, producing two or more generations each year. Several species have more generations per year in the southern parts of their ranges and fewer in the northern parts.

B. Tabanids - The eggs of most species are narrow and cylindrical, and measure 1-2.5 mm (up to nearly 1/8 inch) in length. Each female may deposit 100-1000 eggs, although each batch usually has only a few to a few hundred eggs each. The eggs are arranged in one to several layers and covered with a waterproof secretion that binds the eggs together. The eggs are deposited over water or the preferred larval habitat, on objects such as overhanging plants, sticks, rocks, and emergent vegetation. The eggs may hatch within a few hours (Axtell 1976), or may require 5-7 days of incubation (James and Harwood 1969). The newly hatched larvae fall to the water or soil surface and quickly burrow into the substrate. Larvae of Tabanus and Haematopota are predaceous on insect larvae, snails, earthworms, and other soft bodied animals. Larvae of T. punctifer have been observed feeding on adult toads (Jackman et al. 1983). Larvae of Chrysops probably feed on organic debris. Larvae pass through 4-9 instars, although the number is difficult to determine with certainty for any given species. When ready to pupate, mature larvae migrate to drier soil above the water line, and pupation takes place in the soil about 1 inch below the surface. The head

of the larva is oriented upwards, and in about a day or two the pupa is formed. The pupal period lasts 5-21 days, varying with the species, climate, and season. The adult emerges from the pupal skin and makes its way to the surface, where its wings unfold. Males of a species normally emerge a few days ahead of the main emergence of the females of the same species. Depending on the species, mating may take place almost immediately after emergence, or some time later, after the males have formed a mating swarm. After resting briefly, the adults fly off in search of food. Both sexes feed on nectar and other plant juices, and the females also feed on blood. Females of many species must obtain a blood meal prior to the development of each batch of eggs, and there may be two or three batches laid; however, several species lay one batch of eggs before they seek an animal host. Adult flies may live for as long as 21 days (Burger et al. 1981). Most species have a single generation per year, overwintering as nearly mature larvae and pupating in the spring. A few species appear to have two generations per year, and some of the large Tabanus and Hybomitra species require two years to complete their development.

6. Seasonal Abundance:

A. Black flies - Species that annoy people usually are most abundant in June and July. Several species that produce more than one generation per year may be annoying throughout the warm months; in southern West Virginia, Simulium jenningsi adults are active from April through early November (Anonymous 1984). Other species may be abundant for only a relatively short period of time in a particular season; species of the Prosimulium hirtipes complex are early spring species.

B. Tabanids - Horse and deer flies are most abundant in the early summer. In South Carolina, the greatest number of species and individuals occurs from late April to early July, with a second much smaller peak of activity in September (Adkins 1974). Some species have very restricted flight periods, while others are active throughout the summer.

7. Responses to Environmental Factors:

A. Black flies - Larvae are very sensitive to variations in current, temperature, pH, conductivity, siltation, and other factors. Dams, whether constructed by people or beavers, may favor the development of some species and cause the reduction of others, because of changes in temperature, food, and current patterns (Baldwin et al. 1975; Fredeen 1977). Larvae also are very sensitive to pollution, and are among the first species to be eliminated from streams. Adults respond to the characteristics of their hosts. Thus, adults are attracted to dark colors to feed, but are repelled by green, yellow, and orange; adults also are attracted to CO_2 and certain amino acids (Davies 1978). Biting response is increased by shade, with more flies landing and biting on the shaded side of a host, and biting is greatest during periods of changing, especially falling atmospheric pressure (Davies 1978). Oviposition is inhibited by windy conditions, and species repelled by green, yellow, and orange when seeking a blood meal prefer those colors when seeking a place to lay their eggs.

B. Tabanids - Tabanid larval densities are influenced by soil type and moisture content, and by the distribution of the overlying vegetation (Axtell 1976), but details on the role of environmental factors in larval development are lacking. Adult tabanids are strong fliers, but still are strongly influenced in their activity by the topography of an area; they prefer edge habitats, such as those between dense vegetation and open areas. Schulze et al. (1975) found that in salt marshes tabanids seldom fly higher than 4 ft above the ground and that natural or man-made breaks in the dense upland vegetation provide the major route by which the flies invade areas away from the marsh, although this does not apply to all salt marsh species (Axtell 1976). Tabanid flight activity was greatest between 8 AM and 4 PM on sunny warm days in one study (Schulze et al. 1975), but the activity of individual species responded to these and other factors in various ways in another study (Adkins 1974). Females are attracted to dark colors (black and blue) as opposed to red, orange, white, and silver, and are strongly attracted to carbon dioxide (Adkins 1974).

8. Impact of Black flies & Tabanids:

8.1 Direct Impact:

A. Black flies - Of the 23 species of blackflies reported from New York, about 10 are considered annoying to humans (Stone and Jamnback 1955); and approximately the same number, including some of the same species, are considered annoying in Canada (Fredeen 1977). Black flies are daytime biters and are rarely found indoors. Some species swarm around the head and trunk of humans, and get into eyes, ears, nostrils, and on any other exposed portions of the body. A bite often is unfelt at the time, but soon, depending on the sensitivity of the person bitten, the area around the bite becomes painful and itchy; a wheal may develop and the whole area become hot and fluids may accumulate. Depending on the number of bites and the susceptibility of the individual, headache, fever, nausea, and swelling of the glands may result, a condition known as "black fly fever." This condition lasts about 48 hrs, but the itching of the bites may last for weeks. Similar reactions to the bites of some species of black flies may occur in other animals, and the injection of saliva may cause a toxic reaction that can kill cattle and other large mammals if the flies are sufficiently abundant (Stone and Jamnback 1955; James and Harwood 1969; Jamnback 1973; Fredeen 1975b, 1977).

B. Tabanids - Female tabanids have broad bladelike mouth parts that inflict a deep, painful wound that bleeds freely. In livestock, which may be host to hundreds of flies during a single day, blood loss may be significant. If interrupted in the act of feeding, the persitent fly will quickly return to the same host or a nearby host and bite again. In this way, a single fly may inflict several painful bites on each host.

8.2 Indirect Impact:

A. Black flies - The persistent swarming and biting by black flies can have severe impacts on the ability of people to work in or enjoy the outdoors. In regions with extreme black fly problems, work may come to a virtual standstill during the height of the season. Tourism may be curtailed by much lower numbers of flies than those that disrupt work (Jamnback 1973). Species which swarm in the faces of

cattle may cause them to stampede in an attempt to escape the annoyance. Black flies are vectors of onchocerciasis, or river blindness, in portions of Africa and South America. In North America black flies transmit certain mammalian (but not human) and bird diseases.

B. Tabanids - Tabanids cause sufficient annoyance in some areas, such as along the coast near salt marshes, to interrupt outdoor activities. Animals annoyed by tabanids may fail to gain weight or produce milk normally. Tabanids are vectors of several diseases of people, livestock, and wildlife, including anthrax, loa loa, tularemia, and surra (Krinsky 1976).

9. Natural Enemies:

A. Black flies - Larvae are susceptible to infection by viruses, bacteria, fungi, protozoa, and nematodes (Poinar 1981; Rubtsov 1981; Weiser and Undeen 1981). Several of these are being actively studied as potential biocontrol agents, including the nematodes Mesomermis flumenalis Welch, Gastomermis viridis Welch, and Isomermis wisconsinensis Welch; the bacterium Bacillus thuringiensis var. israelensis de Barjac (B.t.i.); and the fungus Coelomycidium simulii Debaisieux. B.t.i. has shown the greatest promise to date in biocontrol of black flies (see III.3).

Black fly larvae are preyed upon by a wide variety of organisms (Davies 1981), including birds, fish, and many different aquatic and terrestrial insects. Although these are believed to influence black fly population densities, they are not considered to have much potential for biological control.

B. Tabanids - Eggs of tabanids are parasitized by wasps of the families Scelionidae, Mymaridae, and Trichogrammatidae; parasitism rates as high as 35-45% have been reported (Jones 1953; Tashiro and Schwardt 1953). Larvae are susceptible to parasitism by tachinid and bombyliid flies, nematodes, microsporidians, and fungi (Teskey 1969; Axtell 1976). Pupae are parasitized by wasps of the families Diapriidae and Pteromalidae, and adults are parasitized by horsehair worms and mites.

Eggs of tabanids are preyed upon by coccinellid

beetles (ladybird beetles) and katydids (Jackson and Wilson 1965), larvae and pupae are preyed upon by birds, and adults are eaten by dragonflies, digger wasps, and robber flies; but predators probably exert little influence on tabanid populations.

III. BLACK FLIES & TABANIDS MANAGEMENT

1. Population Monitoring Techniques:

A. Black flies - The population monitoring techniques used will depend on the goals of the black fly management program. If the goal is to prevent a problem from developing, efforts will concentrate on monitoring the buildup of larval populations and determining the appropriate time to apply control measures. If the goal is to determine the seriousness and extent of a biting fly problem, monitoring efforts will concentrate on delimiting the spatial and temporal aspects of adult distribution. In either case, the monitoring techniques used may overlap, even though the emphasis is different.

Identification of black flies is difficult, but usually is an important aspect of any control program. Make arrangements with an authority familiar with the species in your area for aid in identification. Ask specifically about pest species, the life history stages required for identification, and the appropriate means of preservation.

Most pestiferous species reach peak emergence in June. Therefore, monitoring of larval habitats should begin by March. Qualitative collections of larvae are made by picking them from solid substrates, such as rocks and sticks, removed from fast flowing water, or by scraping the surface of submerged objects while holding a net downstream. Pupae are best collected by the former method, as they are usually rather firmly attached to the substrate. Preserve larvae and pupae in a vial containing 85% ethanol. Into each vial place a label stating locality, type of substrate, date, and name of collector.

Quantitative collections of immatures may be made by counting all larvae and pupae occurring on a stone or stick of known surface area and converting the results from several such counts into the number of larvae and pupae per m^2. To do this, select stones or sticks that are relatively uniform in appearance from a section of a stream. Quickly remove them one at a time from the stream, wash all larvae off into a white enamel pan with alcohol, carefully

pick pupae and any remaining larvae from the surface, and place all larvae and pupae into a container for transport back to the laboratory for processing. Measure the the surface area of the substrate. Since black fly larvae are restricted to the upper surface and sides where they are exposed to the current, do not include the area of the substrate that was not exposed and suitable for black fly colonization. Examine 5-10 stones or sticks at each site, depending on the size of the stream and the availability of substrate. Alternatively, artificial substrates may be placed in the stream and retrieved after sufficient time has elapsed, usually about three weeks (Fredeen and Spur 1978; Walsh et al. 1981). Many types of artificial substrates have been tried; Carlsson et al. (1981) review many of the designs in use. Walsh et al. (1981) found polystyrene foam balls, firmly affixed to rods to prevent rotation in the current, and placed in black fly larval habitats for 1, 2, or 3 weeks collected more larvae than other types of artificial substrates. Artificial substrates have the advantages of uniformity and replicability compared with natural substrates, and usually are easier to work with.

Aerial nets are used to collect adults along stream banks and swarming around people or livestock. Traps, especially those baited with CO_2, often collect large numbers of female flies. Several traps can be set up and left to operate for several hours at a time, and thus are very efficient. Refer to the reviews by Service (1981) and Tarshis (1978) for more information about trap designs that may be suitable for your black fly monitoring program.

An important component of black fly programs is landing/biting rates surveys. Complaints from park personnel and visitors should be recorded, but the only way to accurately assess the seriousness of a problem is to count the number of flies actually landing on and biting people. For this purpose, a pair of volunteers walks through an area until black flies are encountered. The pair stops and each one counts the number of flies landing on and biting the other over a period of time, the length depending on the number of flies biting (and on the tolerance of the volunteers),

and may vary from a few to 30 minutes. This procedure could be performed by a single person, but less accurately and less efficiently. Collect flies with a net or an aspirator (suction device) and save for identification. All information is recorded on a biting fly survey form, such as the one at the end of this Information Package (Page XIII-33).

Because different species have distinct seasonal peaks of emergence, it is necessary to monitor continually over a period of several months in areas with severe black fly problems.

B. Tabanids - Because of the habitats of larval tabanids and the difficulty of sampling them, it is usually of little benefit to monitor larval habitats. Information on techniques is available in Teskey (1962, 1969).

Adult tabanids are best collected with traps. Different trap designs are reviewed by Roberts (1978). Three of the best designs are the canopy or Manitoba trap, the Maliase trap, and the box trap (Roberts 1978, Pechuman et al. 1983). The canopy trap looks like a beach umbrella made of black plastic below and clear plastic above and having a shining black beach ball suspended by a cord. The trap is placed with the bottom edge of the canopy about 60 cm above the ground and the ball about 30 cm above the ground. The ball serves as a target that attracts the flies which then fly upward into the canopy and are trapped in a jar at the top. The Maliase trap is a fine meshed barrier that traps insects which fly into the mesh and are collected in a jar at the top. The box trap is a square box 32 inches on a side and 16 inches deep and stands 32 inches above the ground on legs. Baffles may be placed between the legs to increase the efficiency of the trap. It is painted white on the outside and black on the inside. Tabanids fly into the trap and are attracted upwards by the light coming through a screen at the top and are trapped by an inverted V made of screen on the inside. No traps collect all species equally well.

Many tabanids will enter and remain in a parked car or truck with the windows left open, and these can easily be collected.

2. Threshold/ Action Population Levels:

A. Black flies - Although the larval stages are the preferred stage for control, there are no guidelines available to help in establishing treatment levels. This situation is not likely to improve any time soon, so the emphasis for the present must be on determining from the results of adult surveys that a problem exists and relying on the results of larval surveys to locate the breeding sites and deciding on the timing of control efforts. Even this strategy is complicated by the very real possibility that many species of black flies can fly into an area from a considerable distance, so that a problem situation may not be caused solely by flies from within the park boundaries. In such a situation, management measures applied to black fly populations within a park may have little noticeable effect on the problem.

People vary widely in their tolerance to black fly annoyance, which makes the establishment of threshold and action levels very difficult. The Canadian Forces have established an action level of 3-5 black fly bites per minute as the point to institute adulticiding of the entire site at Canadian Forces installations (Laird et al. 1982). The park manager must set levels based on the management zone affected and the useage patterns of those areas.

B. Tabanids - No thresholds are established for tabanids. However, the problem is obviated by the almost complete lack of suitable controls.

3. Management Alternatives - Nonchemical:

A. Black flies -

1. Personal protection - Avoid areas of maximum fly activity during peak fly season, usually late May to early July, but variable depending upon environmental factors. Netting can be worn as protection from swarming flies. Nets usually are suspended over the head from a hat and prevent flies from reaching the individual. Long sleeved shirts also provide a measure of protection. Black flies are more strongly attracted to dark than to light clothing (Das et al. 1984); wearing light colored, especially yellow, clothing should afford more protection than wearing dark colored clothing.

2. Environmental manipulation - Concentrations of black flies frequently occur at the outlet of impoundments. Proper design of spillways may help reduce these problems. Vertical spillways are far less suitable as black fly larval habitats than are sloping spillways. Attention to design during the planning of new impoundments or during the renovation of old ones may prevent or help resolve black fly problems.

   LaScala and Burger (1981) report that at least 90% of the population of Simulium decorum could be eliminated by mechanical means from the outlets of a natural and an artificial lake and several other sources in the vicinity of a resort in New Hampshire. Methods used include brushing black flies from their attachment sites with wire bristle brooms and modified pole brushes, directing the flow of dislodged black flies onto the bank with temporary diversion shutes, removing heavily-infested rocks, vegetation, and other breeding site substrates from control sites, and by altering temporarily the outflow from the lake by adding boards to the dam weirs. The authors commenced control efforts when 10-20% of the larval population reached Stage IV (i.e., when the developing respiratory histoblast of the larva is fully developed but unpigmented). Control measures were applied to each major breeding site every 10 days, with an initial expenditure of 10-20 man hours over a two day period. Such methods are labor intensive compared to chemical methods or the use of biological control, but are feasible and economically sound in circumstances where breeding populations are restricted to outlet sites in a relatively confined geographic area.

3. Biological control - Bacillus thuringiensis var. israelensis (B.t.i.) is an extremely promising bacterial agent for the control of black flies and mosquitoes (Anonymous 1979, unpublished mimeographed WHO document; Colbo and Undeen 1980; Undeen and Colbo 1980; Molloy and Jamnback 1981a&b; Weiser and Undeen 1981; Molloy 1982; Rishikesh et al. 1983, unpublished mimeo-

graphed WHO document; Colbo and O'Brien 1984; Pistrang and Burger 1984). B.t.i. is highly specific for black fly and mosquito larvae, having very low toxicity to all other organisms with the possible exception of some Chironomidae (Diptera, nonbiting midges).

Other possible biological control agents include various fungi, viruses, and nematodes. However, none of these are available commercially at this time.

B. Tabanids -

1. Personal protection - The same principles discussed in A.1. apply here, but usually are less effective.

2. Environmental manipulation - Schulze et al. (1975) found that salt marsh horse and deer flies used breaks in the vegetation to move inland from their breeding grounds. It may be feasible in some instances to eliminate or reduce such breaks by planting vegetation to fill in the gaps, and by planning roads and pathways to minimize the creation of new breaks and take advantage of the natural barriers that already exist.

   Attempts to control salt marsh tabanids by manipulating water levels have been made (Anderson and Kneen 1969; Kneen 1968), but the environmental consequences of any extensive program would be too severe to tolerate (Axtell 1976).

   In some breeding areas, such as around small ponds and seepages, it may prove effective to eliminate much of the emergent vegetation in order to concentrate oviposition on the remaining plants. Then those plants, with the adhereing eggs, are removed and destroyed after egg-laying is completed (Pechuman 1981).

3. Traps - Traps to control adults have been tried with mixed success. Pechuman (1981) reported good success with a trap to reduce tabanid attacks on people around a swimming pool, and such traps are used on stud farms in some parts of New York to

protect the horses. In large areas, such as salt marshes, traps may serve more as a psychological than a practical control device. Traps containing hundreds of dead and dying flies may help people feel that something positive is being accomplished, even if the actual effect on the number of flies is minimal.

4. Management Alternatives - Chemical:

A. Black flies -

1. Repellents - N,N-diethyl m-toluamide (deet) is an effective repellent of adult biting flies. It is available in several commercial products as sprays or liquids applied directly to exposed skin. Jackets made of light-weight netting impregnated with deet have been tested and found to be highly effective against most types of biting flies (Grothaus et al. 1976). The mesh material used for the jackets makes them very comfortable in hot weather, but also makes them liable to snagging on underbrush (Col. J. Reinert, USA, Aberdeen Proving Grounds, Aberdeen, MD, pers. comm.). Deet impregnated jackets may be flammable.

2. Adulticides - Insecticides, such as malathion and carbaryl, are available for use as sprays against black fly adults. While these may give temporary relief from swarms in a restricted area, they must be reapplied every few days until the period of peak adult abundance has subsided. Large scale aerial application is possible and might give temporary relief for larger areas. However, black flies are strong fliers that normally disperse several miles from their breeding grounds (Baldwin et al. 1975; Dalmat 1955), and are known to fly hundreds of miles in some instances (Dinulescu 1966; Fredeen 1975a). Because of this, control of adults with insecticides is rarely effective.

3. Larvicides - Because of the ineffectiveness of adult control measures, the preferred method of black fly control is larviciding. Many insecticides have been tried against black fly larvae in streams, some providing good to excellent control (Jamnback 1973;

Walsh et al. 1981; Ogata 1981; Charnetski and Haufe 1981; Fredeen 1974, 1975b). However, resistance to many of these insecticides has appeared, and the lethality of these chemicals to nontarget stream organisms ranges from slight to great (Wallace and Hynes 1981).

Juvenile hormone mimics, such as Altosid®, have been used against black fly larvae in Newfoundland (Thompson and Adams 1979), but the same caveats apply to compounds of this nature as to conventional larvicides.

Consult with your regional IPM Coordinator to determine which pesticide, if any, is best suited to your black fly management program.

B. Tabanids -

1. Repellents - See A.1.

2. Insecticides - Insecticides will kill adult and larval tabanids (Adkins 1974; Wall and Marganian 1973), but the results are minimal and the environmental consequences, especially for larval control, may not justify their use (Axtell 1976; Pechuman et al. 1983).

5. Summary of Management Recommendations:

A. Black flies -

1. Personal protection:
   a. Avoid areas with severe biting fly problems.
   b. Use nets and protective, light-colored clothing.
   c. Use a repellent, such as deet.
   d. Wear a repellent impregnated jacket.
   e. Consider use of a pesticide.

2. Reduce intensity of future biting fly problems:
   a. Establish biting rate threshold and action levels.
   b. Conduct biting rate survey to establish extent and severity of problem.
   c. Survey breeding habitats in problem areas to locate sources of pest species.
   d. Determine feasibility of mechanical controls:

i. If feasibility is high, institute controls.
ii. If feasibility is low, go to e.

e. Consider use of B.t.i. as biocontrol agent.

B. Tabanids -

1. Personal protection: See A.1.

2. Reduce intensity of biting fly problem:
   a. Consider use of traps.
   b. Consider use of barriers.
   c. Consider mechanical/cultural methods to reduce egg-laying sites.

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V. PERSONAL COMMUNICATION

Col. J. Reinert
Aberdeen Proving Grounds
Aberdeen, Maryland

(301) 663-7661

VI. SAMPLE BITING FLY MONITORING FORM

BITING RATE SURVEY

Date: ____/____/____ Monitors: _____

_____

Location: _____

Map Coordinates: _____

Site Description: _____

_____

Weather: _____

Air Temperature: _____

Color and Extent of Cover of Clothing Worn by Monitors:

1. _____

_____

2. _____

_____

Time Monitoring Initiated: _____ Terminated: _____

Elapsed Time (Minutes): _____

Biting Rate:

Number of bites per monitor			Total		Average
Monitor 1. _____	+ Monitor 2. _____	=	_____	÷ 2 =	_____

Average (from above)		Elapsed Time		Number of bites/min.
_____	÷	_____	=	_____

Species Biting: _____

Other Species Present: _____

Specimens Collected: yes / no Notes: _____

_____

_____

SAMPLE BITING FLY MONITORING FORM

BLACK FLY LARVAL HABITAT SURVEY

Date: ___/___/___ Monitors: _____

Name of River/Stream (or nearest named water body): _____

Locality: _____

Map Coordinates: _____

Site Description:

Width: _____ Depth: _____ Flow: _____ Temp: _____

Substrate Type: _____

_____

Aquatic Vegetation: _____

Riparian Vegetation: _____

Type of Samples Taken:

		Number	Surface Area
Natural Substrate Samples	rocks	_____	_____
	wood	_____	_____
	vegetation	_____	_____
	kick net	_____	_____
	Surber/Hess/Box Sampler	_____	_____

Artificial Substrate (specify type): _____

Date Placed in Stream: ___/___/___ Elapsed Days in Stream: _____

Number Placed: _____ Number Removed (this time): _____ Number Remaining: _____

Notes: _____

_____

_____

_____

_____

NATIONAL PARK SERVICE
IPM Information Package

FUNGI, ALGAE, MOSSES, AND BACTERIA ON MASONRY AND STATUARY

Final Report

2 April 1985

Submitted To:

Gary H. Johnston
National Park Service, U.S.D.I.
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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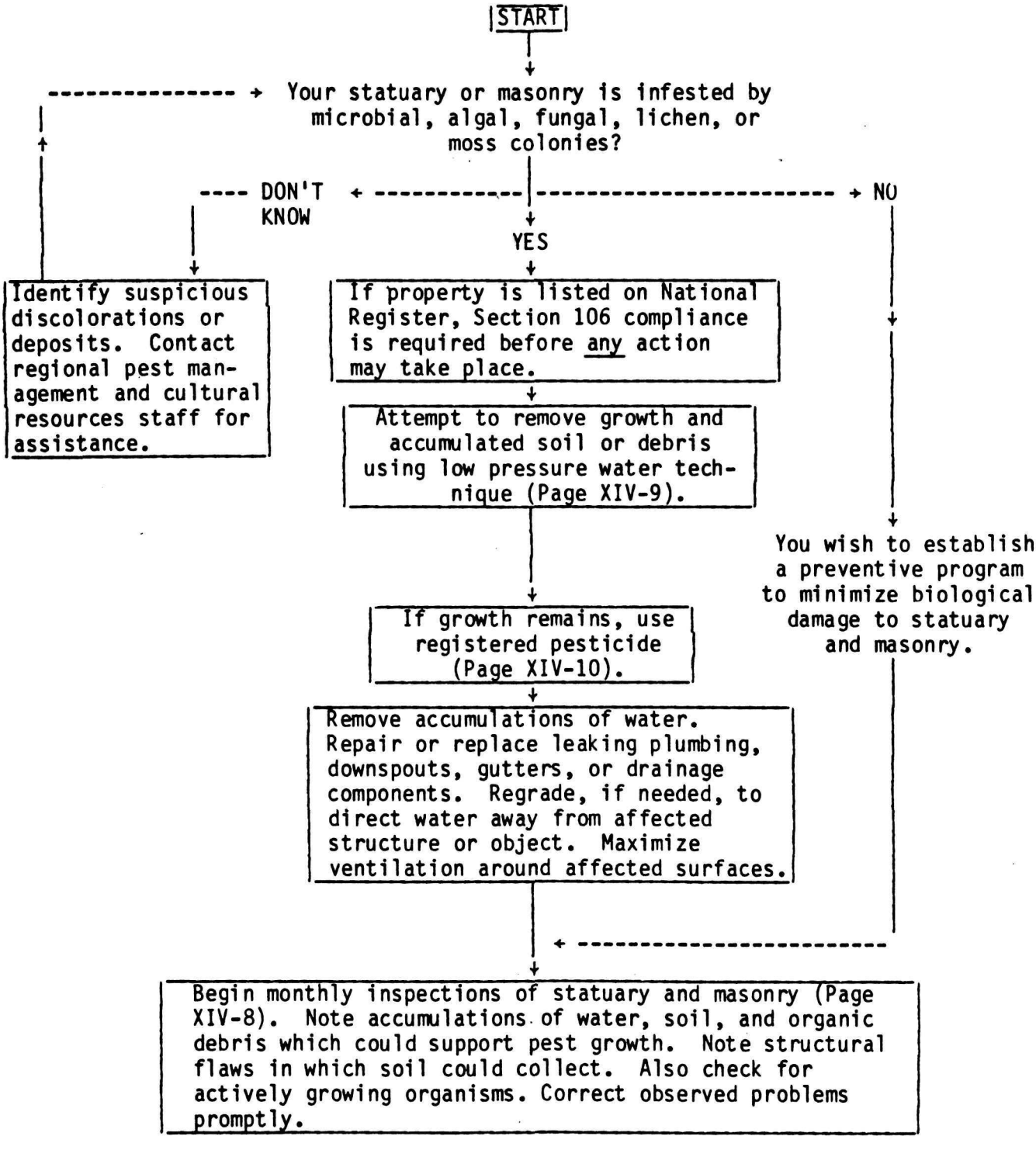
I. FUNGI, ALGAE, MOSSES, AND BACTERIA IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult with NPS pest management and cultural resources staff. All uses of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. BIOLOGY AND ECOLOGY OF FUNGI, ALGAE, MOSSES, AND BACTERIA

1. Pests Described:

Many species of fungi, bacteria, algae, lichens, and mosses may grow on the surfaces of masonry and statuary, and may be considered pests. Complete descriptions of these microscopic organisms are beyond the scope of this information package. Many textbooks and identification guides (e.g., Prescott, 1970; Barnett and Hunter, 1972) are available to aid in the identification of suspected pests. A brief listing of some of the more important pests is presented below:

A. Bacteria - Numerous bacteria are capable of oxidizing sulfur or H_2S to sulfate (SO_4) as a means of generating energy. Among them are members of the families Thiorhodaceae, Beggiatoaceae, Achromatiaceae, Athiorhodaceae, and the Thiobacteriaceae (Davis, et al., 1973). All of these are microscopic single-celled or filamentous organisms. Their gross appearance on statues or masonry is as variously colored, thin patches in moist areas.

B. Algae - The algae consist of groups of relatively simple photosynthetic organisms, which may be single-celled, colonial, or may resemble higher plants in gross structure. Forms found on statuary and masonry are usually blue-green (also called Cyanobacteria) or green in color; and unicellular, filamentous or colonial in structure. Patches of blue-green or green growth may be slimy, depending on the individual species present. Algae grow on moist substrates.

C. Lichens - These are symbiotic associations of algae (usually blue-green or coccoform green algae) with fungi (usually of the class Ascomycetes). The fungus forms a branching mycelial framework which holds and supports the algal cells. The form of lichens may be crustlike ("crustose"), leafy-appearing ("foliose"), or branching ("fruticose"). The colors of lichens vary depending on the particular members making up the association. Lichens are commonly found on bare stone, and are regarded as pioneer species.

D. Fungi - Fungi are nonphotosynthetic organisms which may be unicellular (e.g., yeasts) or filimentous (e.g., mildews) in structure. Various types of fungi may occur on statuary if organic nutrients and water are present. They may appear as spots or patches which may spread to form a fuzzy or powdery mat (colors may vary from blue-green to brown to black) on the infested surface. Additional forms may grow where soil or humus has built up, and may produce mushroom-like fruiting bodies. Fungi require a

constantly moist substrate for growth.

E. Mosses - Mosses are true plants, with green, leafy aerial shoots, and filamentous "roots" (rhizoids). The commonly seen, dominant generation reproduces sexually (see Page 5). The asexual generation (which alternates with the sexual stage in the moss life-cycle), consists of a long stalk topped by a capsule-like sporangium. This stage grows from the top of the parent shoot. Mosses usually can be found in moist, shady places where soil has accumulated, where they can form a carpetlike mat of growth.

2. Geographic Distribution: All of these groups of organisms occur worldwide.

3. Habitats:

A. Bacteria - Most of these organisms occur in moist soil accumulations or in water containing reduced sulfur compounds or organic debris.

B. Algae - Aquatic; many forms may be found on moist surfaces.

C. Lichens - Often found on surfaces of trees or stones. Lichens can survive under dry conditions, and relatively extreme variations in temperature.

D. Fungi - Occur wherever sufficient moisture and a source of nutrient materials can be found.

E. Mosses - Occur in moist, shady areas where soil or debris (including lichens or algal accumulations) exists.

4. Hosts: These organisms do not require hosts as a source of nutrients. They use statuary and other surfaces as substrates on which to grow. Nutrients are obtained from soil and debris that accumulate in cracks and irregularities in the surfaces.

5. Life Cycles:

A. Bacteria - These species reproduce by binary fission to form new cells. None of the sulfate producing species form spores.

B. Algae - Blue-green algae reproduce by binary fission, as do other bacteria. Filamentous green algae may undergo fission of individual cells, but may also

undergo a form of sexual reproduction, involving the migration of the nucleous of one cell through a connecting tube into an adjacent cell. The nuclei fuse, forming a resistant zygote which gives rise to a new colony under favorable conditions.

C. Lichens - The algal and fungal components of lichens reproduce independently (Alexopoulos, 1960). Colonies of the proper pairs of organisms must contact each other for the formation of a lichen to take place. A substrate favoring either component over the other will not favor lichenization; the component not favored will usually die out.

D. Fungi - The life cycles of fungi found on stone surfaces may range from simple to extremely complex in scope, depending on the species. The Ascomycetes, among which are many of the lichen-forming species, arise from single-celled spores. These germinate under proper environmental conditions, and form branching mycelia. New spores may be produced either asexually, at the ends of specialized branches (hyphae); or sexually, within specialized fruiting bodies. Both sexual spores and asexual spores can survive unfavorable conditions.

E. Mosses - The leafy moss plant (sexual generation) develops from a single-celled spore. The spore germinates and gives rise to a filamentous stem, from which shoots and rhizoids branch. Shoots consist of aerial stems bearing whorls of leaves. Male or female sex organs develop at the end of each shoot; some mosses produce both sexes from the same plant, while others produce only male or only female organs on all shoots of a single plant. Sperm are transported by water (e.g., rain water) from male shoots to female shoots, which contain egg cells. A fertilized egg cell divides to form the embryo of the asexual stage, which grows from the female shoot and remains attached to it throughout its life. The tip of the asexual stage is a spherical or ovoid sporangium, which produces the single-celled, weather-resistant asexual spores which survive unfavorable conditions.

6. Seasonal Abundance:

A. Bacteria - Occur whenever liquid water is present. Growth is likely to be least rapid during the cold months.

B. Algae - See A.

C. Lichens - Growth can occur at any time during the year.

D. Fungi - See A.

E. Mosses - Growth is best during the warm portions of the year, but can occur at all times.

7. Responses to Environmental Conditions:

A. Bacteria - Some groups of these microbes require sunlight for sulfur oxidation, while others do not (Davis et al., 1973). All require abundant moisture, and are unable to survive dry conditions.

B. Algae - Algae are photosynthetic, so require light for growth. Since they are aquatic, all algae require continuous moisture for active growth. Most species produce drought resistant spores which can survive unfavorable conditions.

C. Lichens - Can survive conditions unfavorable for most other organisms (including moderate drought). Both algal and fungal components produce spores which can survive adverse conditions.

D. Fungi - Do not require light for vegetative growth, although many species require specific light frequencies for sporulation. Most species produce drought-resistant spores which can survive unfavorable conditions.

E. Mosses - Growth is best in sheltered locations at low light levels, probably due to the drying effects of wind and direct sunlight. Free water is necessary for sexual reproduction. Mosses require a soil-like substrate for growth. Asexual spores can survive adverse conditions.

8. Impact of Fungi, Algae, Mosses, and Bacteria:

8.1 Direct Impact:

A. Bacteria - A major product of the metabolism of sulfate-producing bacteria is sulfuric acid (H_2SO_4), which can dissolve the minerals which make up masonry and stone, and can corrode and pit bronze (Feilden, 1982).

B. Algae - Masses of algae may impart a blue-green or green color to the surfaces on which they occur.

C. Lichens - Lichens occur in variously-colored patches on their substrates; their appearance may detract from the appearance of the substrate (e.g., statue, building surface) itself. In addition, lichens produce organic acids (as metabolic products) which can pit or dissolve masonry, stone or metallic surfaces.

D. Fungi - Fungal colonies or fruiting bodies on statuary or masonry detract from the appearance of the infested objects.

E. Mosses - Mats of mossy growth may detract from the appearance of infested surfaces. In addition, acidic metabolic products of mosses may etch or pit stone, metallic, or masonry construction units.

8.2 Indirect Impact:

A. Bacteria - Damage by sulfate-producing species may produce holes or cracks which can reduce the structural integrity of the infested structure (especially if exposed to freezing temperatures while filled with water), and which can fill with dust or soil particles on which higher plants can grow as weeds.

B. Algae - Produce humus on which other plants can grow.

C. Lichens - See A.

D. Fungi - The spores of many fungi may act as allergins, and cause adverse effects in sensitive visitors.

E. Mosses - See A.

9. Natural Enemies:

These organisms may be attacked by numerous viruses, bacteria, fungi, protozoa, and nematodes. Small mammals, birds, and arthropods may consume these pests. Effective levels of control cannot be achieved using natural enemies alone.

III. MANAGEMENT OF FUNGI, ALGAE, MOSSES, AND BACTERIA

1. Population Monitoring Techniques:

The only effective technique for monitoring populations of microbes and lower plants on statuary or masonry is that of visual inspection. Since the symptoms of damage (e.g., stone pitting) are likely to be indistinct and difficult to detect except in severe infestations, the monitor must check for signs of the organisms, including:

A. Bacteria - Indistinct filmy patches of bacterial slime on moist, infested surfaces. Bacteria may be colorless, or may have green, purple, brown, or reddish pigments;

B. Algae - Blue-green or green staining of surfaces, or masses of filaments or clumps of algal cells. Many algae produce extracellular slime, which may give infested surfaces a slick texture;

C. Lichens - Variously-colored leafy, crusty, or branching colonies. Lichens are dry to the touch, and fragments can easily be broken off. Colonies may grow to more than a foot across;

D. Fungi - Signs may range from powdery or fuzzy masses on infested surfaces, to mushroom-like growths (in areas where humus has built up); and

E. Mosses - Green carpet-like or leafy masses in shady, moist areas in which humus or soil has collected. Usually plants are less than one inch tall.

A sample Inspection Report Form is shown on Page 13. Such a form should be used to record each survey of each structure or object, in order to maintain accurate and useful records.

If unusual or persistant discolorations, growths, or exfoliations occur, contact your Regional IPM Coordinator and Cultural Resources Staff for information on identification of the cause of the problem.

2. Threshold/ Action Population Levels:

Setting threshold levels for populations of these organisms is difficult, because the damage that they may do to masonry, metals and stone is generally slight or undetectable, and because the discoloration caused by mosses, lichens, and algae may be considered an aesthetic asset by park visitors. An indirect effect of infestation of masonry and statuary by microbes and lower plants is that it can serve as an indicator of a potentially more serious moisture problem.

Threshold levels should be set, if desired, after correlating visible growths with visitor/conservator complaints. Inspections should be performed monthly during the growing season (when most growth will occur).

3. Management Alternatives - Nonchemical:

A. Bacteria -

1. Removal of Water - Bacteria require the presence of free water for survival. Therefore, the presence of a bacterial infestation indicates the presence of free water, which itself can be damaging to masonry, stone and metals (Feilden, 1982). Sources of water may include improper drainage, leaking plumbing, and ground water near the surface. Repair or replacement of defective materials, recaulking, regrading, and/or repointing may be necessary to keep excess water away from the infested surface. Improving ventilation (e.g., by pruning nearby foliage) may remove condensation, which can support bacterial growth.

2. Cleaning of Infested Statuary and Masonry -

a. Low-Pressure Water Cleaning - Feilden (1982) and Veloz (1983) recommend loosening deposits with a spray or mist of water, followed by scrubbing of the affected surface with a bristle (not wire) brush, to remove any growths present. Nonionic detergents (e.g., Triton®, by Rohm and Haas; Igepal® by G.A.F.; and Tergitol®, by Union Carbide) will aid in removal of stains and deposits without harming soft stone and masonry surfaces. Biocidal soaps (e.g., Safer Soap®) may also eliminate mosses and other lower plants. These procedures will also remove humus deposits which could support additional growth. Where more abrasion is needed than can be obtained with a bristle brush, Veloz (1983) suggested that stainless steel or fiber glass wool or brushes can be used without risk of discoloring or damaging the treated surfaces. Bronze wool can be used on metal surfaces, but should not be used on marble, limestone, or granite, which could become stained if wire fragments become lodged in crevices and are exposed to moisture.

b. Steam Cleaning - Veloz (1983) reported that combination steam/hot water cleaning (following a water pre-soak spray or drench) can be effective in cleaning accumulated deposits. The author cautioned that steam cleaning can be hazardous to the operator, and suggested that localized expansion of treated materials could be caused by this procedure.

c. High Pressure Water (1000 + PSI) - This is the most aggressive washing procedure available, and may cause damage (e.g., loosening of pins) to statuary and other architectural units (Veloz, 1983). This technique is not recommended for use on masonry.

d. Abrasive Cleaning - Severely discolored metal statuary may require the use of abrasive cleaning procedures. Veloz (1983) indicated that the use of abrasives should only be performed by experienced personnel. Consult with your regional Cultural Resources Staff for additional information before planning any abrasive cleaning procedure.

B. Algae - See 3.A.

C. Lichens - See 3.A.

D. Fungi - See 3.A.

E. Mosses - See 3.A.

4. Management Alternatives-Chemical:

A. Bacteria - Application of a 1% solution of a quaternary ammonium compound (e.g., alkyl dimethyl benzyl ammonium chloride or methyl dodecylbenzyl trimethyl ammonium chloride) has been recommended for removal and inhibition of biologic growths on masonry and stone (Anon., 1975). Dead growth can be removed two weeks after treatment with a nylon or bristle brush and running water.

B. Algae - See 4.A.

C. Lichens - See 4.A.

D. Fungi - See 4.A.

E. Mosses - See 4.A.

NPS does not recommend chemical treatment of statuary or masonry pests except under unusual circumstances. Contact your Regional IPM Coordinator and Cultural Resources Staff prior to initiating any chemical control program.

5. Summary of Management Recommendations:

A. Bacteria, Algae, Lichens, Fungi, and Mosses:

1. Establish a regular inspection and maintenance schedule. Examine surfaces for accumulations of water, soil, or debris, and repair promptly.

2. Prevent accumulation of water on surface by repairing/replacing drainage system, increasing ventilation around surface, correcting grade, and repairing nearby plumbing leaks.

3. Attempt to remove observed growth by washing with low pressure water method. Dry surface thoroughly when finished.

4. If necessary, initiate chemical treatment only after consultation with Cultural Resources Staff and Regional or WASO IPM Coordinator.

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V. SAMPLE INSPECTION REPORT FORM

Structure or Object Name and List of Classified Structures Identification Number (if applicable) and Location_____

_____

Contact_____ Phone_____

Inspection Date_____ Inspected by_____

==========

1. Description of growth:
   Type (if known)_____ Size_____
   Color_____
   Texture_____
   Location(be specific; draw a diagram of infestation site on reverse side of this sheet)_____
   _____
   _____
   _____
   Was sample taken? Yes____ No____
   Date sent for analysis_____ Date received_____
   Name, address of lab_____
   _____
   _____
   Result of analysis_____
   _____

==========

2. Soil accumulations present? Yes____ No____
3. Humus deposits present? Yes____ No____
4. Water accumulation present? Yes____ No____
5. Any structural defects? Yes____ No____
6. Surface ventilation OK? Yes____ No____
7. Debris accumulating? Yes____ No____

==========

8. Recommendations:

==========

9. Date(s) of treatment(s):_____

10. Treatment used:

==========

11. Comments:

NATIONAL PARK SERVICE
IPM Information Package

MOLES & POCKET GOPHERS

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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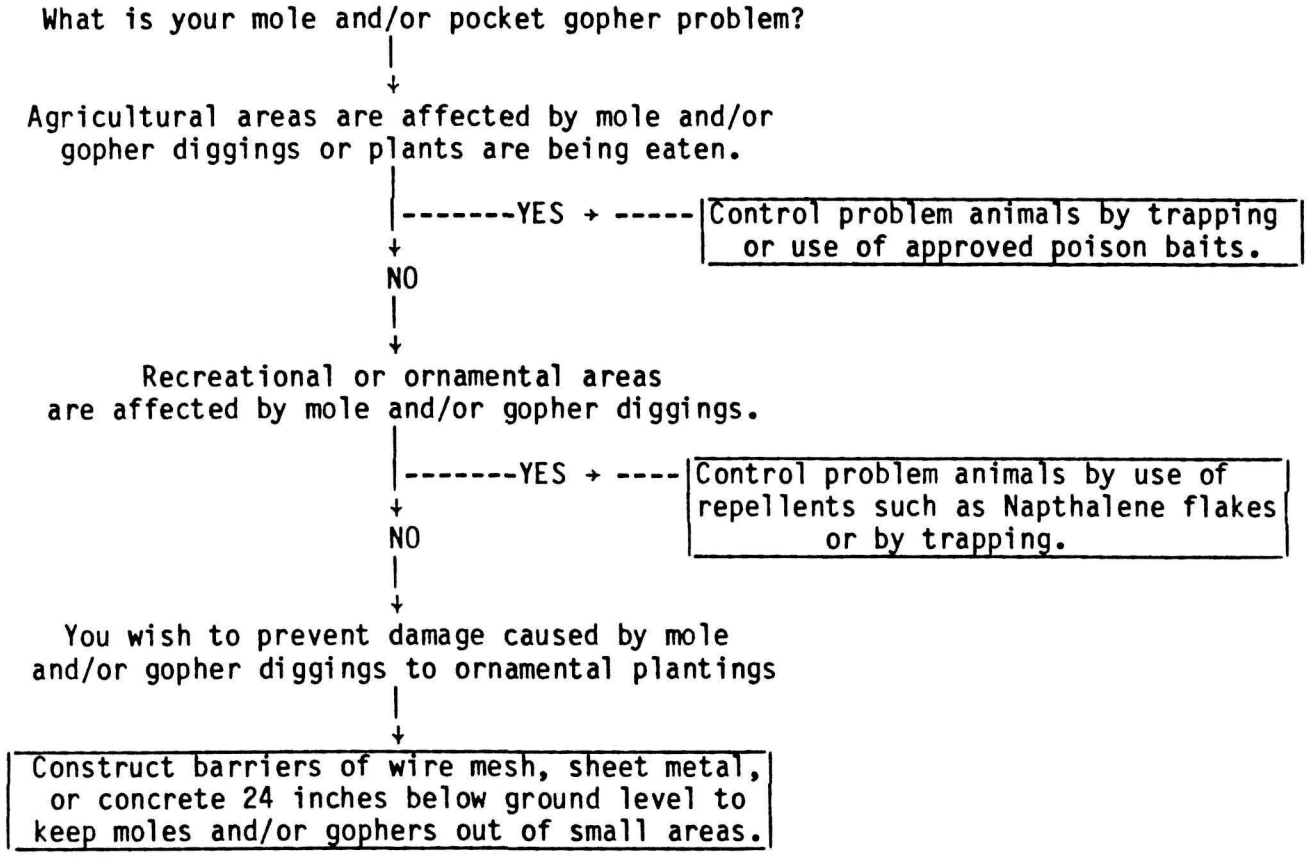
I. MOLES AND POCKET GOPHERS IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



BIOLOGY AND ECOLOGY OF MOLES AND POCKET GOPHERS

Species Described:

1. Moles - Moles are Insectivores, related to shrews. They are members of the family Talpidae. Moles are burrowing mammals, rarely coming to the surface. Seven species in 5 genera occur in the U.S.; the most common species, and the one which is most often a pest, is the Eastern mole (Scalopus aquaticus). Most other species are local or uncommon.

   The adult Eastern mole is 4.5-6.5 inches in body length, with the tail an additional 1-1.5 inches. It weighs 2.5-5 ounces. The front feet are broader than long, with the palms facing outward for digging. The snout is pointed with the end naked, and the nostrils open upwards. The tail is naked. The eyes are pinhead size and covered with thin skin; there are no external ears. The fur has a silvery sheen; slate gray in the North, and brown to gold in the South and West. There are 6 mammae. The skull has 36 teeth.

   See Burt and Grossenheider (1964) for illustrations and detailed descriptions of North American moles.

2. Pocket Gophers - Pocket gophers are rodents, and comprise the family Geomyidae. There are fifteen species in three genera in the United States.

   Pocket gophers are burrowing mammals and are seldom seen on the surface. They are 4.75-9 inches in length, depending upon the species, and weigh up to a pound. They have external cheek pouches which are fur-lined and reversible, opening on either side of the mouth. The large, yellow incisors are always exposed in front of the mouth, even when it is closed. The front claws are large and curved for digging, the tail is short and sparsely haired or naked. The eyes and ears are small but functional. The fur is light brown to yellowish.

   See Burt and Grossenheider (1964), for illustrations and detailed descriptions of all species of pocket gophers.

2. Geographic Distribution:

1. Moles - Three species of moles occur in the East. The seven western species occur primarily on the Western slope of the Rockies. Moles are found throughout the U.S., except in the Rocky Mountain region and the Great Basin.

   The Eastern mole occurs from Massachusetts to Florida along the East Coast. It ranges as far west as eastern Colorado and Texas, north to Michigan and Wisconsin. It is not found in the mountains of West Virginia and Pennsylvania.

   See Burt and Grossenheider (1964) for detailed range maps.

2. Pocket Gophers - Pocket gophers occur throughout the Western and Southern portions of the U.S. One or more species occur in the following states: Washington, Oregon, California, Nevada, New Mexico, Arizona, Utah, Idaho, Montana, Wyoming, Colorado, Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Minnesota, Wisconsin, Iowa, Illinois, Indiana, Missouri, Arkansas, Louisiana, Alabama, Georgia, and Florida.

   See Burt and Grossenheider (1964) for detailed range maps for each species.

3. Habitat:

1. Moles - Moles prefer moist sandy loams. Meadows, fields, gardens, lawns, and golf courses are common habitats. Moles tend to avoid dry soils, and are seldom found in heavy clays, or stony or gravelly soils.

2. Pocket Gophers - Pocket gophers prefer slightly moist soils which are suitable for burrowing. Most species inhabit soils similar to those best suited for moles, but some western species are found in rocky soils in mountains.

4. Hosts:

1. Moles - Moles feed almost exclusively on earthworms, grubs, and soil inhabiting insects. Tunnel systems are used as traps; worms falling from the ceiling are captured and eaten. Moles will store prey for later consumption after immobilizing it with a bite. Moles also eat some plant material. Due to their high metabolic rates, moles eat 25% to 100% of their body weight in food every day.

2. Pocket Gophers - Gophers feed primarily on roots and tubers underground. Some surface vegetation is eaten after being pulled into the burrow. Gophers sometimes forage aboveground.

5. Life Cycles:

1. Moles - Moles are primarily solitary except during spring breeding season. After a gestation period of 6 weeks, 2-5 young are born in a grass-lined nest 18-24 inches below the surface. There is 1 litter per year. The young are naked at birth, independent after 1 month, and capable of breeding after 1 year. Moles are active year-round, day and night. Moles may live for several years.

2. Pocket gophers - Pocket gophers are solitary except during breeding season. They breed once per year in the northern part of their ranges and twice a year in the south. The plains pocket gopher (the most common species) breeds in April to July in the north, and twice between February to August in the south. The southeastern pocket gopher (the common eastern species), breeds in any month of the year, and usually has 2 litters of young. After a gestation period of 18-19 days, 1-3 young are born. The young are independent within 3 months, and are capable of breeding at one year of age. Pocket gophers are active day and night the year round, and are seldom seen aboveground.

6. Seasonal Abundance:

Populations of moles and gophers are highest just after the young are born and before natural mortality factors become prevalent.

7. Response to Environmental Factors:

1. Moles - The major environmental factors affecting populations of moles are soil type and associated availability of prey. Prey density is thought to account for the low densities of moles in most areas. A population of 2-5 moles per acre is considered high in most areas of North America, although high populations may not be injurious.

2. Gophers - Pocket gopher populations are affected by soil type and availability of preferred vegetation, primarily roots and tubers. There is some evidence for territoriality in males of some species. Males tend to have home ranges of approximately 2200 square feet, females have home ranges of about 1300 square feet. A density of 7-10 pocket gophers per acre is considered high.

8. Impact of Moles and Pocket Gophers:

8.1 Direct Impact:

1. Moles - The major impact of moles is the production of ridges of earth which are thrown up during tunneling. These ridges may have aesthetic impacts on lawns, golf courses, cemeteries, parks, and other ornamental areas. Tunneling does not damage the turf area.

2. Gophers - Pocket gophers are undesirable in fields and lawns primarily due to the mounds of earth thrown up during burrowing. These mounds may interfere with harvest of crops or recreational use of land. Gophers also eat plants and plant parts and are considered pests in agricultural areas, particularly alfalfa growing regions.

   Gophers have damaged irrigation canals and dikes by burrowing, and have damaged tree roots and lead-sheathed underground cables.

8.2 Indirect Impact:

Moles are considered beneficial in most circumstances due to their insectivorous diets, and the transport and aeration of soils caused by their tunneling activities.

Moles are often blamed for damage to plants caused by voles or other mice which may inhabit the tunnel systems.

Pocket gophers may be considered beneficial in many circumstances due to the transport and aeration of the soil during burrowing. It is estimated that each gopher transports over 2 tons of soil to the surface each year (Henderson, 1982).

9. Natural Enemies:

Moles and gophers are preyed upon by a wide variety of animals including snakes, weasels, coyotes, badgers, hawks, owls, dogs, and cats.

III. MANAGEMENT OF MOLES AND POCKET GOPHERS

1. Population Monitoring Techniques:

Moles and gophers are best monitored by noting ridges and mounds caused by burrowing. Control should be attempted only for those individuals which are directly interfering with activities.

1. Moles - Mole activity can be determined by the heaved ridges from near-surface tunnels, and by circular mounds of earth pushed to the surface.

2. Gophers - Pocket gopher activity can be identified by the presence of numerous large earth mounds. Gophers push earth up in lateral burrows which are 15 inches away from and at right angles to the main tunnels located 10 inches below the surface.

2. Threshold/ Action Population Levels:

Since naturally occuring population densities of moles and gophers are normally low, there are no established population thresholds. As noted above, control should be directed at individual animals, not on an area wide basis for entire populations.

3. Management Alternatives - Nonchemical:

1. Moles - Moles may be kept from small areas such as flower beds by placing sheet metal, concrete, or wire mesh barriers around the perimeter of areas to be protected. The barrier should extend downward for 2 feet to prevent moles from tunneling beneath it.

Populations of moles in turf areas may indicate high populations of insects (e.g. white grubs) which may be detrimental to turf. Monitoring of insect populations should be initiated before undertaking control of moles. See Turf Insects IPM Package for applicable techniques.

Traps in surface tunnels are effective control devices. Two types of traps, scissors and harpoon, are recommended for use in mole control. Several traps should be used. In large areas such as golf courses, 25-100 traps may be needed to reduce populations enough to offset immigration and reproduction.

Mousetraps can be used to trap moles. Tunnels are cut across, the trap is set perpendicular to the tunnel, with the trigger in the tunnel, or two

traps are set back to back. A box may by placed over the hole to block light. It is not necessary to bait mousetraps used for mole control.

Pitfall traps may be used in circumstances where mechanical traps are not desirable. A large can is placed below the tunnel with the top of the can even with the bottom surface of the tunnel.

Traps should be placed where the surface tunnel is straight for several feet. Moles use straight tunnels more often than winding tunnels. To determine which tunnels are used most often, collapse a portion of the tunnel and check back the next day. Active tunnels will have been repaired.

The active burrow should be opened and the scissors trap placed in the tunnel with the jaws encircling the burrow. Harpoon traps are set straddling the burrow. Mark a map with all trap locations for retrieval. The opening should be covered with cardboard or wood. Check traps twice a day, if a trap is not sprung in 24 hours, move the location of the trap. If traps are set but no moles are captured, reset the trap further back in the tunnel, and reset the trigger.

See Henderson (1982) for details on mole management through trapping.

2. Gophers - Undergound fences can be used to protect tree plantings from gophers. A cylinder of 1 inch or smaller wire mesh 12 inches in diameter and 18 inches tall should be placed in the hole around the tree during planting. The top of the wire should be 1-2 inches under the soil surface to allow cultivation around the tree.

   Trapping pocket gophers is similar to mole trapping. There are three types of pocket gopher traps in use; the box trap, the spring trap, and the Macabee trap.

   Traps should be set near fresh gopher workings. To locate the tunnel, push the fresh mound aside and look for the earth plug where the gopher has filled a lateral tunnel. This can be determined by the subsoil, which is different from the surface soil in color. Dig down until the open burrow is reached (from 2-16 inches down). Set the trap far back in the tunnel. Loose soil can be used to partly cover the buried trap.

Attach a wire to the trap and anchor it to a stake. This will prevent a predator from dragging the gopher and trap away during the night.

Cover the entrance either partially or completely, and mark the site with flags for easier checking later. If a lateral tunnel is opened, set one trap. If a main tunnel is opened, set two traps back to back.

Pocket gophers travel their entire burrow system every few hours. Air coming into the system from the opening will also attract the gopher. As the gopher checks the burrow or tries to plug the opening, it will be caught in the trap. Traps should be checked every 4-8 hours.

Repeated misses by a spring trap, or a blocked burrow where the set traps have been buried, require adjustment in the trap or in trapping procedure.

4. Management Alternatives - Chemical:

1. Moles - Chemical control of moles has met with some success. Before considering chemical methods, consult with your regional IPM coordinator.

   Food source removal discourages moles and generally results in lower populations, but tunneling may increase before moles leave the area.

2. Pocket gophers - Pocket gophers have been controlled using poison baits such as chlorophacinone, or zinc phosphide on corn placed in burrows (Case, 1983). When soil conditions are right, a "burrow builder" which creates and baits artificial burrows intersecting the gopher's burrow system, has been used with some success (Henderson, 1982).

   Fumigants have been used in the past without much success due to the extent of the burrow systems, leakage into the soil, and plugs constructed within the system to keep out predators. Generally fumigants will not be recommeded for use on NPS lands.

   Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Protect small areas with barriers of sheet metal, screen mesh, or concrete.

2. Before trapping in turf areas, monitor turf insect populations which may be attracting moles. The presence of moles may indicate future turf insect problems.

3. Trap problem moles and gophers using approved traps in burrow systems.

4. Use approved poison baits to control individual problem animals.

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NATIONAL PARK SERVICE
IPM Information Package

GRAIN AND FLOUR PESTS: INDIAN MEAL MOTH, CONFUSED FLOUR, SAWTOOTHED GRAIN, CIGARETTE, AND DRUGSTORE BEETLES

Final Report

10 July 1985

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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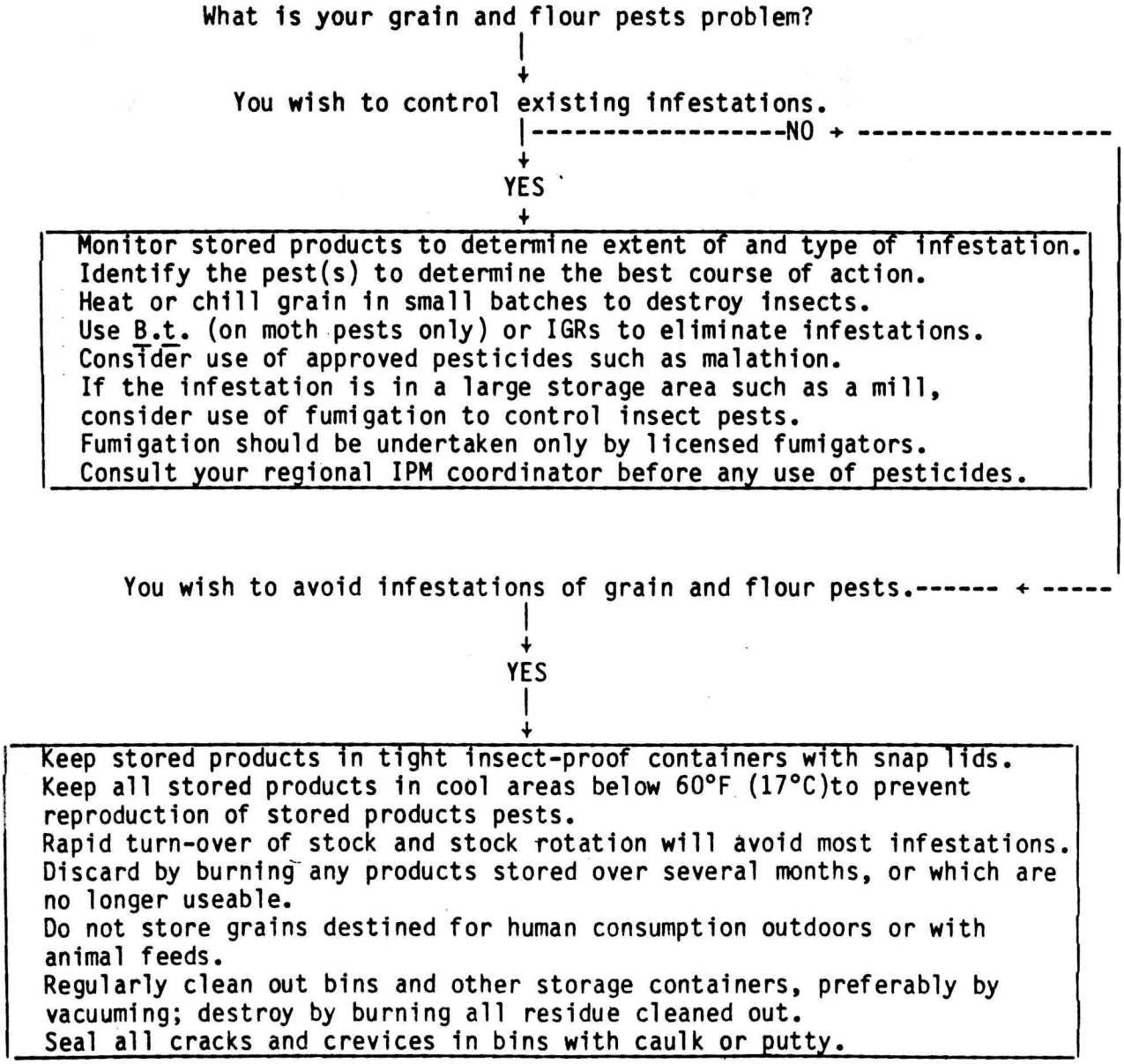
I. GRAIN AND FLOUR PESTS IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. GRAIN AND FLOUR PESTS BIOLOGY AND ECOLOGY

1. Species Described:

Many species of insects and mites feed upon stored products. A thorough examination of the life histories and control measures of all major stored product infesting pests is beyond the scope of this Information Package. The following insects were chosen as being the most important stored product pests in the NPS. See Anonymous (1978) for descriptions and illustrations of important stored products insects and mites. See Okumura (1982) for keys to the more common stored products pests.

1. Indian meal moth - Plodia interpunctella (Hubner). Adults are moths (Lepidoptera, family Pyralidae) with wingspans of approximately 3/4 inch (20 mm). This species can be distinguished from other grain-infesting moths by the distinctive marking on the forewings which are reddish brown with copper luster on the distal (outer) two-thirds, and dirty white on the proximal (inner) third. Caterpillars (larvae) are dirty white, sometimes tinged with green or pink, and up to 1/2 inch long when fully grown. Caterpillars produce silk which becomes very noticable when the grain is undisturbed for long periods.

2. Confused flour beetle - Tribolium confusum Jacquelin du Val. Adults are shiny, flattened, oval, reddish brown beetles (Coleoptera, family Tenebrionidae) 1/7 inch (3.5 mm) long. The head and upper thorax of the adult is densely covered with minute punctures. The wing covers are ridged longitudinally, and sparsely punctured between the ridges. Adult beetles have nonfunctional wings and do not fly. The antennae are gradually clubbed on the last 4 segments. Eggs are small and white, with sticky surfaces, and adhere to boxes, sacks, and other containers. Larvae are white, tinged with yellow, and about 3/16 inch (1.5 mm) long when fully grown. Pupae are naked, and white, turning yellow, then brown as the insect matures.

3. Sawtoothed grain beetle - Oryzaephilus surinamensis (L.). Adults are slender, flat, brown beetles (Coleoptera, family Cucujidae) 1/10 inch (2.5 mm) long. The thorax bears 6 sawtooth-like projections on either side which give the species its common name. Although they possess functional wings, adult beetles do not fly. Larvae are 1/8 inch (3 mm) long when fully grown, and possess 3

pairs of legs plus one pair of abdominal prolegs.

4. Cigarette beetle - Lasioderma serricorne (Fab.) Adults are small, stout, oval beetles (Coleoptera, family Anobiidae), 1/10 inch (2.5 mm) long. They are reddish yellow or brownish red. The head is bent down from the thorax at a 90° angle, giving the adult a humpbacked appearance when viewed from the side. Antennae appear sawlike. Larvae are hairy, dingy white, with brown head capsules.

5. Drugstore beetle - Stegobium paniceum (L.). Adults are similar to cigarette beetles, but more cylindrical in cross section, and more elongate in proportion to the width. Adults are light brown with silky pubescence, and striated wing covers. They can be distinguished from cigarette beetles by the 3-segmented club at the tip of the antennae. Adult size is about 1/10 inch (2.5 mm). Larvae are white with brown head capsules, and less hairy than cigarette beetle larvae.

2. Geographic Distribution:

All of the insects discussed in this Information Package have been distributed by commerce world-wide. They may occur wherever grains or other food sources are stored.

3. Habitat:

The insect pests discussed in this Information Package occur in stored grains or grain products. They are seldom found outdoors, but some species of grain-infesting insects may occur in grain fields where they attack grain on the stalk.

4. Hosts:

1. Indian meal moth - Caterpillars of this species feed on a wide variety of foods including grains, grain products, dried fruits and nuts. Adults do not feed.

2. Confused flour beetle - Feeds on farinaceous material in granaries, mills, warehouses and wherever grain and grain products are stored. This species is unable to attack undamaged grain, and usually is associated with other grain-damaging insects. It is usually attracted to flour having a high moisture content. This species has also been observed feeding on peas, shelled nuts, spices, museum specimens, soap, and arsenic-poisoned rodent baits. Most of the damage is caused by the larvae.

3. Sawtoothed grain beetle - Feeds on all foods of vegetable origin including grains, flours, meals, breakfast foods, livestock and poultry feeds, copra, nuts, and dried fruits. Both larvae and adults cause damage.

4. Cigarette beetle - Feeds on tobacco and other stored products including spices, drugs, dried meats, poisons such as rat baits, seeds, and grains left in sacking for long periods of time. Dried plants are a common source of infestation. This insect is a serious pest of herbarium specimens. Larvae and adults are considered pestiferous.

5. Drugstore beetle - Feeds on all items of vegetable or animal origin including human mummies and spices (particularly red pepper). This species received its common name from its practice of feeding on toxic or pharmaceutical drugs such as belladona, aconite, and strychnine. Also known to feed on paper products, books, and wooden building supports. Drugstore beetles are reported to have pierced tin foil and sheet lead to get to food. Both larvae and adults cause damage.

5. Life Cycles:

1. Indian meal moth - Females deposit 100-300 eggs singly or in groups on food material. The eggs hatch in 1-5 days, depending on temperature. Caterpillars feed on a wide variety of stored foods. Pupation occurs in spun silk cocoons within the substrate. In warm weather, the cycle from egg to reproductive adult takes 6-8 weeks; under less favorable conditions, the life cycle may last nearly a year. Moths may breed year-round indoors.

2. Confused flour beetle - Females deposit an average of 450 eggs in flour or food where adults live. Eggs are small, white, and covered with a sticky surface which causes them to adhere to containers. Reinfestation often occurs when new material is added to empty containers with eggs adhering to them. Eggs hatch in 5-12 days. The small, wiry, wormlike larvae feed on grain dust, flour, or the broken surfaces of grain kernels. There are 5-18 larval instars, depending upon conditions. In summer, the cycle from egg to adult takes approximately 6 weeks, but may be prolonged by cold weather. Adults may live up to 3 years.

3. Sawtoothed grain beetle - Females deposit 45-285 eggs among foodstuffs or in crevices in grain kernels. Eggs hatch in 3-8 days into small, slender, white larvae which crawl about actively. Larvae develop into pupae in about 2 weeks during warm weather, over a month in cooler areas. Larvae pass through 2-4 instars, depending on temperature. Cocoons are constructed by gluing fragments of substrate around the larva. Pupation lasts approximately 1 week. In summer, the cycle from egg to adult takes approximately 4 weeks, but may be prolonged by cold weather. Adults are active in winter in heated buildings, but do not normally reproduce unless humidity levels approach 70%. There are up to 7 generations per year under optimal conditions.

4. Cigarette beetle - Females deposit up to 100 eggs in seeds or grains left undisturbed in sacking for long periods of time, or in tobacco and other stored products. Eggs hatch in 6-10 days. Larvae construct galleries in foodstuffs and feed for up to 10 weeks. The pupal state requires 2-3 weeks but life cycle duration is quite variable. There may be up to 6 overlapping generations under favorable conditions, but in temperate areas 1 generation per year is normal. Adults live 2-4 weeks after emerging from pupae.

5. Drugstore beetle - Life cycle is similar to 5.4. Eggs are usually deposited singly in foodstuffs such as undisturbed grain left in storage for long periods. The larvae pupate from 2-5 months, depending upon temperature and other factors. Pupation lasts 12-18 days. There can be up to 4 generations per year, but 1 per year is normal under average circumstances.

6. Seasonal Abundance:

Stored products pests are abundant wherever sufficient food is available and temperatures are moderate. Infestations can occur at any time of the year indoors when temperatures and humidities are favorable. See the chart on page XVI-10 for temperature ranges for each species.

7. Responses to Environmental Factors:

Stored food insects are primarily of tropical or subtropical origin and thrive under warm, humid conditions. With few exceptions they are unable to resist exposure to low temperatures (below 60°F) for more than a few days, and do not hibernate. They are all adapted to living on food of low moisture content.

8. Impact of Grain and Flour Pests:

8.1 Direct Impact: The direct impact of stored products pests is the destruction or fouling of grain and other agricultural products in storage making them unpalatable. Infested grain or grain products are unacceptable for human consumption.

8.2 Indirect Impact: The major indirect impact of stored products pests is the cost of inspection, detection, and control.

Grain attacked by insects while in storage becomes susceptible to mold and other microorganisms.

9. Natural Enemies: Several species of parasitic Hymenoptera are sometimes found in stored grain; members of the Pteromalidae, Braconidae, Bethylidae, and Ichneumonidae all parisitize grain insects, and are commonly seen in warehouses and mills. Scenopinid flies (window pane flies) prey upon eggs, larvae, and pupae of grain pests in warehouses and mills (Anonymous, 1978). Larvae and adults of the confused flour beetle are known to prey upon caterpilars of the Indian meal moth (Okumura, 1982). Some pest species may be canabalistic under some circumstances (e.g., overcrowding or lack of available food resources).

III. GRAIN AND FLOUR PESTS MANAGEMENT

1. Population Monitoring Techniques:

Stored product insects should be monitored by regular inspections (2-3 week intervals) of stored foodstuffs, empty bins, and other areas where foodstuffs are kept. A hand lens is useful in monitoring for eggs, larvae, and some of the smaller species. When monitoring, look for the presence of insects in various life stages, holes in packaging, webbing on food material, cast skins, and feces. Special attention should be paid to foodstuffs which have been in storage for long periods of time.

In areas where large quantities of grains are stored, efforts should be made to monitor throughout the grain mass. Sampling large quantities of grain is difficult. Temperature probes to detect "hot spots" indicative of mold or insect activity are used by commercial elevator operators. The Loschiavo trap is sometimes used for monitoring large grain masses. This trap consists of a section of perforated metal or plastic pipe probed into the grain and left in place for several days, then removed and inspected for insects. It is not known what volume of grain a trap collects insects from, nor if the trap is biased for any species. Traps usually collect only adult insects and do not provide a grain sample for quality evaluation. Such traps may be useful in determining if insects are present in stored grain (McGaughey and Lai, 1982).

Phermomone traps developed by researchers are avaiable for monitoring stored products pest populations. Pheromones have been identified for 19 stored products pest species (McBride, 1984).

2. Threshold/ Action Population Levels:

The presence of stored product insects in stored foodstuffs destined for human consumption should trigger control measures. Stored product insects in foodstuffs used for animal feeds or in products used for demonstration purposes (i.e., flour or grains from historic mills), and not destined for human consumption, should be controlled if insects are readily noticeable.

3. Management Alternatives - Nonchemical:

Sanitation is the best way to prevent stored product infestation. All bins should be cleaned regularly; cracks and crevices should be filled with caulk or putty, and painted over. Vacuuming is the best way to clean bins. If possible, products should be stored in insect-proof plastic containers with snap lids. Newly-hatched Indian meal moths and confused flour beetles can penetrate openings as small as 0.12 mm, and could move between the threads of jar lids (Okumura, 1982).

Rapid turn-over of materials helps to prevent infestations; many stored product pests are found in foodstuffs which are kept for long periods.

Heating materials to 122°F (50°C) for 1 hour results in near complete mortality of stored product insects. Small batches of material can be heated to 150°F (66°C) for 20 minutes. Material should be spread shallowly and stirred every few minutes.

Stored products may be exposed to microwaves to destroy insect pests. Control of stored product insects by microwaves is based on dielectric heating. Dielectric heating effects are produced in relatively poor conductors of electricity. When a mixture of grain and insects are exposed to microwave radiation, the insects heat at a faster rate than the grain itself due to differences in dielectric constants (Boulanger et al., 1969). Insects subjected to microwave or certain other radiations may be heated to lethal temperatures while the grain is undamaged (Hamid et al., 1968). Boulanger et al., (1969) report 100% mortality in confused flour beetle populations when infested grain is heated by microwaves to 113°F (45°C) for 75 minutes. See also Kirkpatrick et al. (1972) for further information on microwave and other radiations for stored product pest control.

Stored product pests can be killed by exposure to low temperatures (0°F or -18°C) for periods of not less than 4 days or 50°F for 30 days (Okumura, 1982). This procedure is recommended for small batches only, to allow temperatures at the center of the material to become low enough to kill insects.

Pheromone traps have been recommended as replacements for chemical pesticides for control of low-level populations (McBride, 1984). For further information, contact:

W.E. Burkholder
537 Russell Laboratories
Department of Entomology
University of Wisconsin,
Madison, Wisconsin
53706

Stored product insects have minimum temperatures and relative humidity requirements for population increase. Grains or grain products stored below minimal conditions will be less susceptible to infestation. The following table is taken from Howe (1965):

Insect	Minimum Temperature	Optimum Temperature Range	Minimum Relative Humidity %
Indian Meal Moth	64°F 18°C	82°-90°F 28-°32°C	40
Confused Flour Beetle	69°F 21°C	86°-92°F 30°-33°C	1
Sawtooth Grain Beetle	69°F 21°C	87°-93°F 31°-34°C	10
Cigarette Beetle	71°F 22°C	89°-95°F 32°-35°C	30
Drugstore Beetle	62°F 17°C	77°-83°F 25°-28°C	60

Nuts may be stored in jars with carbon dioxide (dry ice chips) in a cool place. Jars should be sealed only after all dry ice chips have fully sublimated to avoid cracking or explosion of the jars. Nutmeats stored in this method are relatively free of infestation by moth pests, see Olkowski et al. (1979) for details.

4. Management Alternatives - Chemical:

Insect growth regulators (IGRs) affect insect development at early stages and can slow population buildup, especially where reinfestation rates are slow. IGRs can be used in small amounts, and pose no residue problem. They are reported to be nontoxic to mammals and produce no teratogenic or mutagenic effects in warm-blooded animals (Loschiavo, 1976). Methoprene and hydroprene prevent emergence of adults from pupae of confused flour beetle at 20 ppm, while 5 ppm inhibits oviposition. Methoprene at 1 ppm prevents the emergence of adult sawtooth grain beetles, while the same effect is caused by hydroprene at 5 ppm (Loschiavo, 1976).

Malathion used in storage containers has been reported to control Indian meal moths, confused flour beetles, and sawtooth grain beetles for up to 8-12 months (Spitler et al., 1976). Malathion-treated sawdust has been used to control flour beetles in empty storage structures. Sawdust treated with 2% malathion gave nearly 100% mortality for 4 weeks on concrete and 16 weeks on wood and steel surfaces (Mensah and White, 1984).

Evidence of resistance to malathion and other chemical pesticides has been reported (Nickle, 1979).

Bacillus thuringiensis (B.t.) gives excellent control for Indian meal moth and other grain infesting moths (McGaughey, 1982). Follow label instructions when using this or any other pesticide on stored products.

Label instructions should be followed and care must be taken not to allow insecticides to drift onto open food or utensils. Food containers should be protected from pesticide-treated shelves by sheets of paper placed on shelves after the pesticide has dried.

In severe infestations of large-scale grain storage areas such as mills, silos, and elevators, fumigation with methyl bromide may be warranted. Fumigation should be carried out by professional licensed fumigators.

Consult your regional IPM Coordinator to determine which pesticide, if any, may be suitable to your IPM program.

5. Summary of Management Recommendations:

1. Practice good sanitation to prevent infestations of stored products. Keep stored products in tight containers; keep unused containers clean and free of grain scraps or dust. Stored products should be used rapidly and not overlooked in stock turnover. Storage temperatures and relative humidities should be kept as low as possible.

2. Monitor using pheromone traps and visual inspection.

3. Infestations in small grain masses can be controlled by heat or cold. Conventional, microwave, or other radiation heating may be used.

4. Use B.t. (on moth pests only) or IGRs to control larval populations in stored products.

5. In large-volume storage areas, consider fumigation with approved fumigants by licensed fumigators.

6. Consult with regional IPM Coordinator prior to using any pesticide.

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NATIONAL PARK SERVICE
IPM Information Package

GYPSY MOTH

Final Report

2 August 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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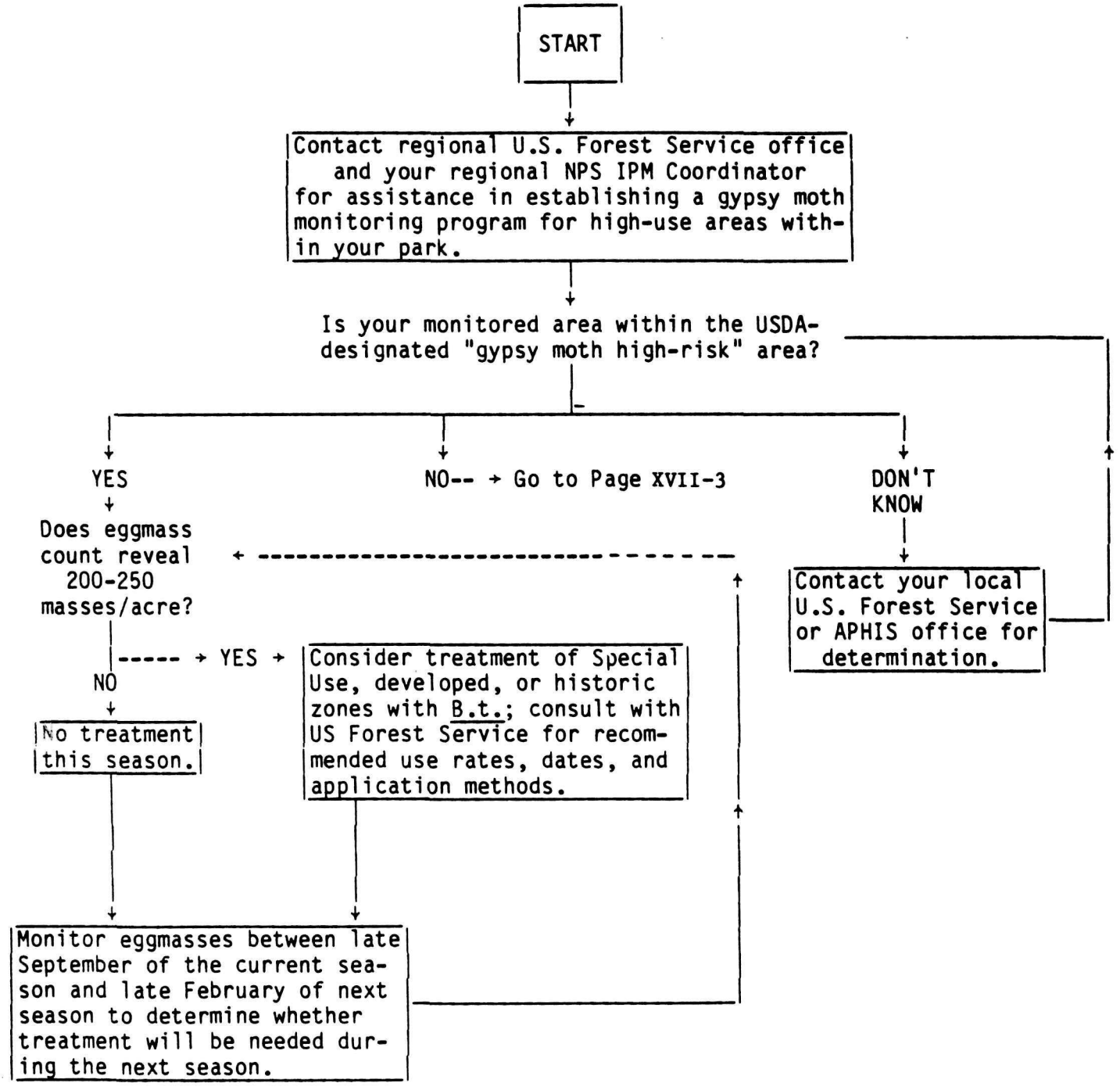
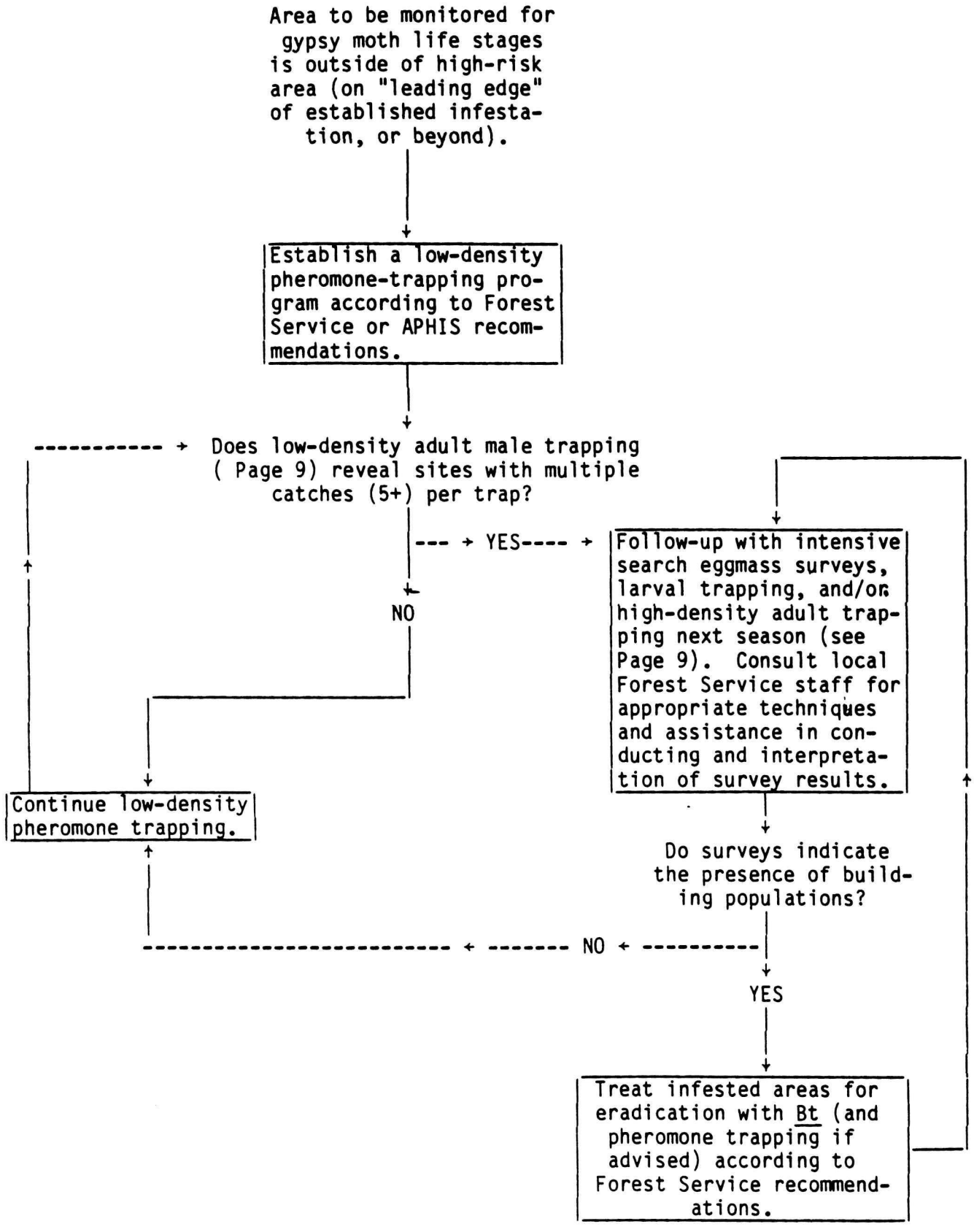
I. GYPSY MOTH IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to EPA label instructions and be approved on an annual basis by the Director, NPS.




Area to be monitored for gypsy moth life stages is outside of high-risk area (on "leading edge" of established infestation, or beyond).
Establish a low-density pheromone-trapping program according to Forest Service or APHIS recommendations.
Does low-density adult male trapping (Page 9) reveal sites with multiple catches (5+) per trap?
YES
NO
Follow-up with intensive search eggmass surveys, larval trapping, and/or high-density adult trapping next season (see Page 9). Consult local Forest Service staff for appropriate techniques and assistance in conducting and interpretation of survey results.
Continue low-density pheromone trapping.
Do surveys indicate the presence of building populations?
NO
YES
Treat infested areas for eradication with Bt (and pheromone trapping if advised) according to Forest Service recommendations.

II. BIOLOGY AND ECOLOGY OF GYPSY MOTH

1. Species described:

Lymantria dispar (L). The adult female moth is dirty-to-creamy white, with faint and/or dark bands across the forewings. Wingspan varies from 2 to 2 1/2 inches. The female's body is stout and densely covered with hairs, and her antennae appear thread-like.

The male is much darker than the female; the wings are dark brown with black bands across the forewings. The wingspan is about 1 1/2 inches, and the antennae are feathery. The abdomen is narrower than the female's. Although the wings of both sexes are fully developed, female gypsy moths fly very rarely, if at all.

Eggs are globular, whitish, and about 1 mm in diameter. They are laid in oval clusters of 75 to 1,000 (averaging 400-500), covered with buff-colored hairs from the female's abodomen. Clusters may be 1/2 inch to 2 inches long.

Fully-grown caterpillars may be 2-3 inches long. The basic color is a buff-yellow to brown or gray. Each body segment has 6 knoblike protuberances (tubercles). The five frontmost tubercles on the dorsal surface of the larva are blue; those behind are red. Each tubercle is topped by a tuft of yellow or brown hairs, which may be up to half a body-length long. A yellow line runs along the top surface from the head to the last body segment. The dark-colored head has additional yellow lines. The true legs are dark red. Younger instars (1-4) are similar in appearance to older larvae, but have proportionately longer body hairs.

Pupae are teardrop-shaped, chocolate to dark red-brown in color, and are rounded in the front and tapered in the abdomen. Male pupae are 2/3-1 inch long, while females may be up to 1 1/3 inches long. A few hairs may occur on the head and each abdominal segment. Each pupa is enclosed in only a few strands of silk.

See McManus and Zerillo (1978) for a photographic guide to all life stages of the gypsy moth.

2. Geographic Distribution:

The gypsy moth is an exotic species which was accidentally introduced into Massachussetts in 1869. Since then, it has spread throughout New England (excluding northern Maine) to many areas in New York; most of

Pennsylvania, Delaware and Maryland; central Michigan; and all of New Jersey. Scattered infestations have been reported in North and South Carolina, Ohio, Alabama, Tennessee, Indiana, Illinois, Wisconsin, Minnesota, Arkansas, California, Oregon, and Washington (Gary Moorehead, personal communication).

3. Habitat:

Temperate and boreal deciduous forests are the favored habitats of Lymantria dispar. Damage is often greatest under open forest canopies (where there is relatively little undergrowth) and at forest edges. High population densities (or transport as a result of human activities) may result in migration to nearby or distant softwood forest, urban, and/or agricultural environments, all of which may support gypsy moth populations on available plant foliage.

4. Hosts:

The leaves of more than 500 species of trees and other plants are eaten by gypsy moth larvae (adults do not have fully-developed mouthparts, and are not believed to eat). Trees can be grouped according to their suitability as gypsy moth hosts:

a. Trees favored by all instars include alder; all oaks; gray and river birch; basswood; all willows, poplars, apples, all hawthorns; and box elder. Oaks, especially white oak, are considered the most favored foods.

b. Trees fed on by all instars, but not as likely to suffer complete defoliation, include paper birch and larch.

c. Trees fed on (but not favored) by all instars, and suffering only light defoliation, include: all maples, yellow and black birch, all elms, sassafrass, all hickory, black gum, black cherry, and hornbeam.

d. Trees favored only by older larvae include all pines, all hemlocks, all beeches, all spruce, and southern white cedar.

e. Trees unfavorable to all larvae (thus nearly immune to attack) include all ash, butternuts, locusts, dogwoods, American holly, balsam fir, sycamores, tulip tree, red cedar, and black walnut.

Trees under stress (e.g., drought) are attacked more than are healthy trees, and the largest gypsy moth outbreaks are correlated with periods of below-average summer rainfall.

5. Life cycle:

Only one generation of gypsy moths is produced each year. Adults usually emerge from pupae during July, but if populations are high, emergence can be earlier. Males usually appear 1-2 days prior to females. Males fly in zig-zag or (less commonly) straight patterns and are attracted to vertical objects such as tree trunks, where they might find females. Most males will fly less than 1 mile (usually less than 200 meters) from the site of their emergence from the pupae. Females are not known to fly.

Several hours after emerging, females release a sex pheromone (from abdominal glands) in "bursts." Males are attracted to this chemical, and follow the odor trail (and visual cues, within 1-3 yards) to land along-side a receptive female. Mating may last up to 1 hour, after which females begin depositing eggs. Multiple mating is common among males, but rare among females, since the release, of the pheromone is inhibited by mating. Adult moths live about 1 week.

Most eggs are laid within 24 hours after mating. Generally, egg clusters are found on tree trunks, crevices, under loose bark, under or on rocks, tree stumps, foliage, or vehicles. Between 8 and 9 months are spent in the egg. Hairs from the female's abdomen surround the eggs, providing protection from winter temperatures as low as -20°F. Larvae are fully formed inside the eggs about a month after laying, but most lose water content and cease development until spring. Some larvae do hatch in the fall, but do not fully develop. Most larvae complete their development and emerge from the eggs about the time that local trees are producing new leaves.

Most larvae will hatch from an eggmass within a week, but the hatch period may be up to a month from masses in cool, shadowed, or high-altitude areas. Newly hatched larvae are about 3 mm long, and remain near their eggmass if the weather is rainy or if temperatures are below 45°F. Once they have left the eggmasses, larvaes are

attracted to light and move upwards, spinning a thread of silk, until they reach the top of whatever object they hatched on. They then rely on the wind to carry them to new locations, using their silk threads as balloons or parachutes. Most larvae migrate even if they hatch on a source of available food.

Larvae feed first on new leaves, during daylight hours. Peak feeding periods occur during early morning and late afternoon hours. When not feeding, the young larvae stay on the undersides of leaves, where they form a silk mat on the leaf surface for attachment.

Molting occurs at intervals of about one week, to allow the larvae to grow and expand. Males usually undergo four molts and females usually undergo five, but up to nine have been recorded.

After the third molt, larvae begin resting in sites other than leaves, and begin feeding at night (with peaks in the late evening and before dawn).

At the end of the larval period, each larva surrounds itself with a sparse silk net, rests for about 2 days, and becomes a pupa. The pupa breaks out of the larval cuticle, turns dark brown, and remains in its silk net for about 14 days if male, or 16-17 days if female. When development is complete, the newly-formed adult breaks out of the pupal skin, expands its wings over a period of several hours, and begins its adult life.

6. Seasonal abundance:

Eggs hatch between mid-April and late May. Larvae are abundant for about 40 days after hatching, until perhaps mid-July at latest. The pupal stage lasts for about two weeks; pupae are generally present until late July at the latest. Adults live 6-10 days, so may be found from early July until late August. Only egg masses are found between the death of one year's adults and the hatch of the following year's larvae.

7. Responses to environmental factors:

A. Weather and Climate:

1. Temperature - Exposure of eggs to temperatures below 32°F for extended periods or to less than -9.4°F for short periods is lethal. Exposure of larvae to freezing temperatures may be lethal. Larval growth is accelerated by exposure to high temperatures (around 90°F).

2. Moisture - Heavy rainfall at hatch may result in drowning of larvae. Rainy weather during the first larval instar can delay migration, and cause larvae to congregate on the undersides of leaves. The duration of this instar may increase under these conditions. Extended congregation may stress larvae enough to make them susceptible to nucleopolyhedrosis virus "wilt" (see Page 14).

3. Light - Gypsy moth larvae are attracted to light just after hatch, leading them to move upward to sites from which they can be moved by wind. Young larvae (instars 1-3) feed during the day, while older larvae alter this behavior, resting during the day and feeding at night. Adult emergence is apparently triggered by daily light/dark cycles as well.

4. Wind - Larvae are dispersed mainly by wind. Newly-hatched larvae trail silk as they climb to treetops or the upper surface of the objects on which they hatched. These larvae are most active during the daytime, when winds are most active. When they encounter wind, they arch their bodies (to catch the wind) and extrude a silk thread which may act as a balloon or parachute. In addition, first instar larvae are covered with comparatively long hairs, which increase their buoyancy in air.

B. Density Of Population - Crowding of larvae can accelerate development. Crowding during the first instar may prolong the dispersal (prefeeding) period, induce additional instars, and result in the production of larger, more prolific adults.

Another change induced by crowding is a phase polymorphism, in which crowded larvae and adults become lighter than normal in color.

Perhaps the most noticeable behavior change induced by larval crowding is the wandering of large larvae during daylight hours.

8. Impact of Gypsy Moth:

8.1 Direct Impact:

The gypsy moth is one of the most effective defoliators of hard and softwood trees. In addition to aesthetic problems and reductions of lumber stands due to repeated defoliation, forests suffering gypsy moth attack may suffer increased risks of fires, due to canopy reduction and accelerated drying of litter. Effects of defoliation on watershed output are unclear at present. In recreation areas, unsightly defoliated

areas and wandering larvae can result in decreased visitor use and revenues.

8.2 Indirect Impact: Repeated defoliation of forest trees can lead to increased susceptibility to other pest damage, and alteration of ecologic succession at affected sites (Doane and McManus, 1981).

9. Natural enemies: Many natural enemies of the gypsy moth have been found (Doane and McManus, 1981), including the following:

A. Pathogens:

1. Bacteria - Bacillus thuringiensis; produces a toxic protein during sporulation which, when injested by a larva, causes a lethal disease.

   Streptococcus faecalis; a strain of this organism has been found to kill larvae.

2. Nucleopolyhedrosis virus - This virus causes a "wilt" disease of gypsy moth larvae which ingest it. The dried bodies of infected organisms serve as inoculum for additional infection.

B. Parasites - More than 40 parasitic flies and wasps have been introduced to control the gypsy moth. Among those which have become eatablished are the egg parasites Oocentrus kuvanae and Anastatus disparis, and the larval parasites Apanteles melanoscelus, Brachymeria intermedia, Rogas indiscretus and R. lymantriae. Simons, et al. (1979) list these as well as many native parasites. Native insects do not effectively control the gypsy moth.

C. Predators:

1. Ground Bettles - Four Calasoma species feed on larvae and pupae. C. sycophanta has been successfully released in the southern portions of the gypsy moth range in the U.S.

2. Soldier Bugs - Podisus species.

3. Birds - Cuckoos, orioles, robins, bluejays, crows, chipping sparrows, chicadees, vireos, grackles and catbirds feed on larvae.

4. Mammals - Shrews and white-footed mice eat larvae and pupae, and may be a major factor in maintenance of low gypsy moth populations.

III. GYPSY MOTH MANAGEMENT

1. Population Monitoring:

Several methods are available for monitoring gypsy moth populations. The choice of method should be based on the population level suspected, location of sampling site in relation to the established U.S. infestation area, and resources available. The USDA Forest Service currently provides gypsy moth survey assistance to any Federal agency on request, and should be consulted if you wish to have a survey conducted.

A. Adult Male Trapping - These techniques involved the use of special traps (made of plastic-coated paperboard) with a sticky inner surface, and which are baited with a synthetic form of the sex pheromone produced by receptive female gypsy moths. The trap currently used for gypsy moth surveys by the USDA Forest Service and the Animal and Plant Health Inspection Service (APHIS) is fully described by Schwalbe (1979). Although several variations of the trap design are manufactured, the USDA-approved design is regarded as the most effective, and should be used. A list of current suppliers of USDA-approved traps can be obtained from your regional Forest Service Office, or from the State and Private Forestry Division of the Forest Service, Washington D.C. (203-235-1560).

Pheromone traps should be placed before male moths begin flying (about mid-June). Schwalbe (1979) describes the use of pheromone traps to detect low gypsy moth populations, and to define specific areas of infestation. Pheromone trapping is an effective technique only for relatively low populations, so is recommended for use in areas outside (or on the edges) of established infestations.

The interpretation of pheromone trapping results is subjective; no direct relationships between numbers of trapped males and eggmass counts (see below) have yet been found. Generally, if traps used in a low-density (1 per 3-4 square miles) survey catch large numbers of males (5 or more) in a season, a high-density (16-36 traps/square mile) survey is performed the following season, to identify foci of infestation for possible treatment (Gary Moorehead, personal cummunication).

B. Larval Trapping - The collection of gypsy moth larvae, while not yet useful in quantifying infestations, can serve as another early indicator of a low (e.g., recently established, but building) population. The most convenient method involves tying a 12" wide burlap band around the trunk of each tree to be monitored so that the top 6" of the band can be pulled down over the bottom, making a shaded flap in which larvae will hide during daylight hours. Bands should be monitored two times each week, and any trapped larvae should be destroyed. The presence of gypsy moth larvae in such traps indicates that a population may be developing in the vicinity of the trap site, and that other survey methods should be used to determine whether treatment is required. Tar-paper wrappings and plastic tree flaps have also been used (instead of burlap) for this technique (Noel Schneeburger, personal communication).

C. Eggmass Counting - Several methods have been developed for determining the number of gypsy moth eggmasses in an infested area. Eggmass counts can be done from September through February, allowing more time for interpretation of results, recounts of doubtful results, and selection of treatments than is afforded by the other methods discussed above. The choice of a particular counting method can be made on the basis of availability of resources (e.g., time and personnel) to conduct surveys, and the expected population level. Currentlyused methods include:

1. Threshold walk - An observer walks through the area to be monitored, counting any new (current season) eggmasses he/she sees. The walk ends when the count reaches a predetermined number (see Threshold/action population levels). This method gives no approximation of the actual population level in an area, but it is easily done, and in areas of high gypsy moth population (e.g., established infestation areas) it is useful in making a treat/no-treat decision using accepted threshold values.

2. Five-minute walk - The observer and a companion-guide walk through the area to be monitored for a five-minute period; each counts every detectable new eggmass. The average of the two counts is determined, and converted to an approximate number of eggmasses by the following equation:

Average number of eggmasses observed	X 20	+ 15 =	Estimated number of Eggmasses per acre

The estimate of eggmasses/acre can be compared to established threshold levels to determine whether treatment is necessary. The equation above was supplied by Noel Schneeberger, of the USDA Forest Service. This technique is most useful in areas of high gypsy moth populations.

3. Fixed-radius plot - The observer counts every new eggmass within a circle of radius 18.6 feet about a chosen point. This count, multiplied by 40, gives the approximate count per acre, which can be compared to known threshold values. This technique is effective where populations are low, and eggmasses may be difficult to find.

4. Fixed-and variable-radius plot counts - This method is described by Wilson and Fontaine (1978). It is more sophisticated than those already described,, provides data which can be statistically compared to data from other areas, and requires significantly more effort than the methods noted above. This method is too time-consuming to be effective for counting high egg mass populations, but is excellent for low populations.

5. Intensive search - Used for very small populations (i.e., no evident defoliation, but with multiple adult male catches in pheromone traps), this method simply involves examination of all surfaces (in the vicinity of traps with trapped males) for eggmasses, including under bark flaps, under rocks, and in tree holes. Intensive searching is recommended to support pheromone trapping for the discovery of new infestations.

In addition to merely providing an estimate of the number of eggmasses in an infested area, these methods can provide the opportunity for the observer to judge the health of the gypsy moth population. Eggmasses which are thick and of large size (about that of a 50 cent piece), showing little or no parasite damage (such as small holes), and containing large quantities of undamaged, fertile eggs indicate

a healthy population, which may require treatment. In many cases, a numerically large population producing small eggmasses, and/or showing predator/parasite damage, may be declining, and not require treatment. Of course, any eggmasses found in areas outside the established U.S. infestation area may represent the spread of the gypsy moth, and may require treatment, since isolated infestations may often be eradicated (see Page 16). Within the infested region, management of the moth population to prevent undue defoliation is the best approach, since eradication is impossible.

D. Defoliation monitoring - To date, efforts to determine a numerical relationship between the gypsy moth population level in an area and the amount and severity of defoliation to be expected in that area have been only partly successful at best. Current defoliation thresholds are rough estimates. Therefore, in addition to directly sampling the moth population in a particular area, site managers may wish to indirectly track zones of defoliation to determine:

- o Where to treat otherwise-unidentified moth populations;
- o Where to set up traps next spring; and
- o The progress of existing infestations.

Defoliation is generally monitored (during the period of peak larval development) in the following ways:

1. An observer may make estimates of percentage defoliation of particular trees by walking through the infested area and examining tree crowns through binoculars. A slightly more comprehensive method involves using the Fixed and Variable Radius Plot design noted above (under Eggmass sampling), and again estimating the percentage defoliation noted on each tree observed. Comparing photographs of a sample area taken at regular intervals will allow the observation of changes in canopy density due to defoliation. These methods are very time-consuming, and are subject to errors of interpretation. They are discussed by Talerico (Doane and McManus, 1981).

2. An observer may fly over the area to be monitored in a fixed-wing aircraft, sketching zones of light, medium, or heavy infestation on a U.S. Geological

Survey map of the area. Talerico (in Doane and McManus, 1981) details the procedure and interpretation of such maps. As in ground observation methods, interpretation of the results is largely a matter of experience.

3. Aerial photographs (on false-color infrared film) can be used to accurately identify the locations and severity of defoliation. The U.S. Forest Service presently cooperates with the U.S. EPA and NASA to prepare such photos, and provide training for photo interpretors in gypsymoth-infested states. If you believe that the use of such a system would benefit your gypsy moth control program, contact your NPS Regional IPM Coordinator for further information on Forest Service programs.

2. <u>Threshold/ action population levels:</u>

The following population values are currently used by the USDA Forest Service and APHIS in their gypsy moth management programs. It should be noted that the goal of the Forest Service program is to maintain moth populations below levels producing significant defoliation, while that of the APHIS program is the eradication of isolated gypsy moth outbreaks.

A. For areas in established infestation zones:

200-250 eggmasses/acre; moth population will produce noticeable defoliation. Treatment is recommended for high-use recreational areas (campgrounds, trailer parks, other areas with transient traffic).

B. For areas outside established infestations:

5 or more male adults per delta trap (USDA pheromone trap), count obtained using low-density trapping (1 trap per 3-4 square miles); triggers follow-up high-density trapping (using a regular grid of 16-36 traps/square mile; the trap density should be greater in high-value areas), intensive searches for eggmasses, and eradication treatments where infestations are located by these methods.

3. Management alternatives - nonchemical:

A. Bacillus thuringiensis - This spore-forming bacterium produces a crystalline protein (during sporulation) which is toxic to the larve of many species of butterflies and moths, including the gypsy moth. Predators and parasites of the gypsy moth are not harmed by the toxin, nor are humans, plants, or other animals. A complete review of the properties and action of B.t. toxin can be found in Doane and McManus (1981). B.t. is an effective alternative to chemical pesticides used against L. dispar, and is currently available in a number of commercial products, including Dipel (Abbot Laboratories); Bactospeine, Leptox, and Novabac-3(Biochem Products); Certan and Thuricide (Sandoz), SOK-Bt (TUCO), and Gypsy Moth Caterpillar Control (Reuter). Label directions should be followed at all times.

B. Nucleopolyhedrosis virus (NPV) - This virus is the cause of an endemic "wilt" disease of gypsy moth larvae in the U.S. and Europe. A review of the natural occurence (gypsy moth NPV is a major cause of naturally-occuring moth population declines), culture, and testing of NPV as an artificially-applied larvacide is included in Doane and McManus (1981). Currently, NPV is not used in gypsy moth control programs due to ineffectiveness and the lack of an easily-applied formulation (Noel Schneeberger, personal communication).

C. Other predators and parasites - While many naturally-occuring predators and parasites are known, none has been sufficiently well studied to permit commercial development or large-scale release. The best way for a site manager to make use of available predators and parasites is to use management alternatives (e.g., B.t. or no treatment) which will not adversely affect them, so that they can function as a part of the gypsy moth IPM program. See Doane and McManus (1981) for a detailed discussion of predator/parasite research. Eggmass surveys and larval surveys can include observations of predator/parasite presence as a guide to maximizing their effectiveness. Contact your regional Forest Service office for assistance in conducting such surveys in your area.

D. Genetic control - The release of sterilized male moths has been attempted as a means of control. Females which mate with sterile males should not produce offspring, since females usually mate only

once. This method is expensive, and is probably only effective in controlling small, isolated pockets of infestation. See Doane and McManus (1981) for a detailed discussion of the USDA sterile-male release research program.

E. Favored-host removal - Since the demise of the American chestnut as the dominant overstory tree in Eastern U.S. deciduous forests, oaks have become the dominant species. Unfortunately, oaks are also the favored hosts of the gypsy moth throughout its range. In the absence of external control measures, repeated defoliation of favored trees may result in a shift of dominance to nonhosts and lessfavored hosts, such as maples. This will, ultimately, reduce the magnitude of the gypsy moth problem in these areas. While selective removal of favored gypsy moth hosts is an impractical (at best) solution for most park sites, selection of planting material for areas under development (e.g., urban parks) to exclude favored hosts is certainly feasible. See Section II.4 for a list of less favored and nonhost trees.

F. Regulatory control - APHIS has designated a large area of New England, the Middle Atlantic States, and portions of Michigan as "gypsy moth high risk areas" (Anonymous, 1983). Individuals moving household or recreational items from these areas into or through other areas of the U.S. must have such items inspected and certified gypsy-moth-free by a USDA-trained inspector. Since gypsy moth larvae may hide on (and females frequently deposit their eggmasses on) exposed surfaces of vehicles, camping equipment, and other items, inspection of the vehicles and equipment belonging to park visitors from high-risk areas may enable park personnel to discover and destroy eggmasses and other gypsy moth life stages which could give rise to new infestations. Distribution of educational materials (e.g., Anon., 1983) to prospective visitors to all parks outside the "highrisk" areas, along with the erection of prominent informational displays outside park boundaries are recommended as methods to encourage visitors to voluntarily participate in such a program. Contact your regional NPS IPM Coordinator or local APHIS office for aid in setting up such a program.

The establishment of a pheromone-trapping program in areas of high vehicular traffic and other visitor use is recommended as an adjunct to any inspection

program, to permit the discovery of isolated infestations caused by eggmasses or other life stages slipping through the inspection program. Contact your local Forest Service office for details and assistance in conducting a trapping program.

4. Management alternatives - chemical:

A. Gypsy moth pheromone - The sex pheromone produced by female gypsy moths to attract males (cis-7,8-epoxy-2-methyloctadecane, or 'disparlure') has been synthesized. While disparlure is widely used to monitor adult male population levels (see Section III.1.), it has also been used to control small populations (e.g., isolated outbreaks along the "leading edge" of the infestation) by trapping males in pheromone-baited sticky traps, and by disrupting mating behavior. Currently, USDA-APHIS uses pheromone traps (at 3/acre, or 2,000/square mile) in conjunction with double applications of Bacillus thuringiensis in attempts to eradicate small outbreaks in selected areas of the U.S. (Gary Morehead, personal communication). If you suspect such an outbreak in your area, consult your local Forest Service representative for information and assistance in evaluating the feasibility of and/or setting up an eradication program.

B. Chemical insecticides - Insecticides currently registered for gypsy moth control include dimilin, carbaryl, acephate, and trichlorfon. NPS policy states that these pesticides may only be used in (historic or developed) park areas in which B.t. or other biological methods (or pheromone trapping) are ineffective. Contact your regional NPS IPM Coordinator for further information.

5. Summary of Management Recommendations:

The USDA Forest Service is responsible for conducting gypsy moth population monitoring programs in all Federal lands. Each park manager should contact his/her regional USDA-FS office for assistance in setting up an appropriate gypsy moth monitoring program for high-use areas. For further information regarding USDA-FS services, contact the:

Director, Forest Pest Management
State and Private Forestry Division
USDA Forest Service
FTS: 235-1560 (commercial area code 703)

In historic and developed areas (including campgrounds, visitor facilities where shade is an important attraction, and specimen trees), survey programs may trigger treatments with Bt for suppression or eradication. Under NPS policy, natural areas may receive no treatments; existing natural enemies must be allowed to exert their long-term effects in such areas.

IV. BIBLIOGRAPHY

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NATIONAL PARK SERVICE
IPM Information Package

HYDRILLA

Final Report

11 MARCH 1985

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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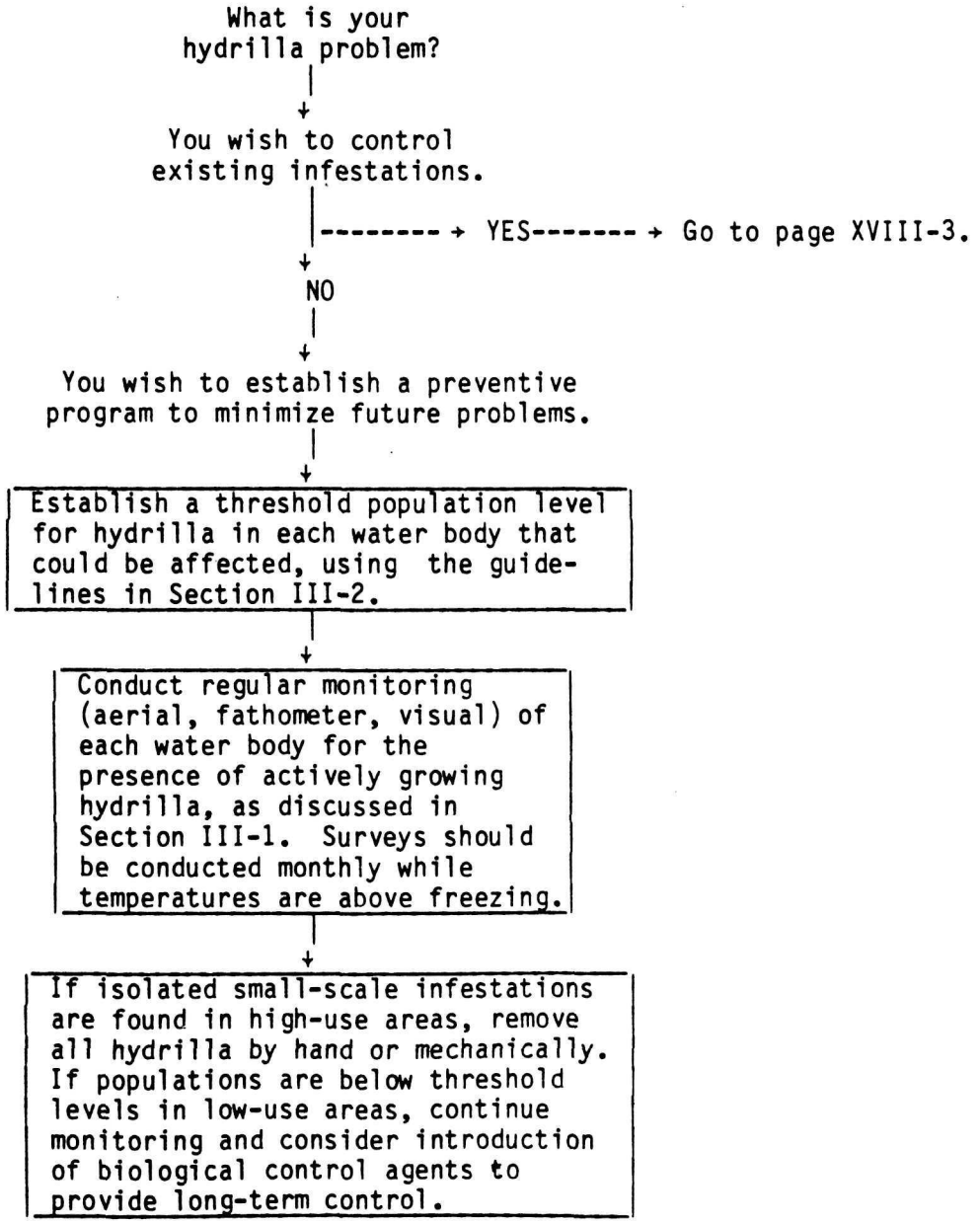
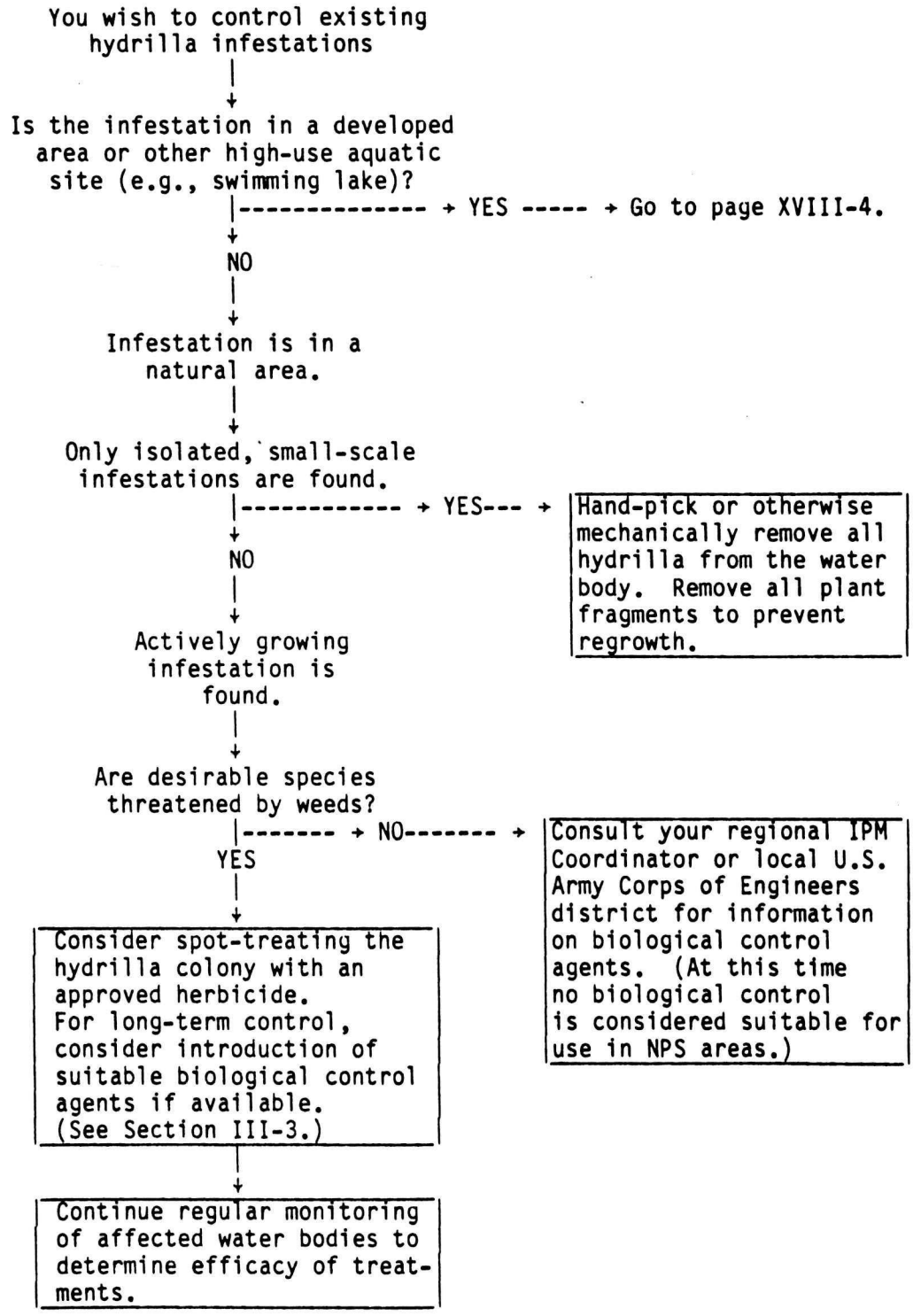
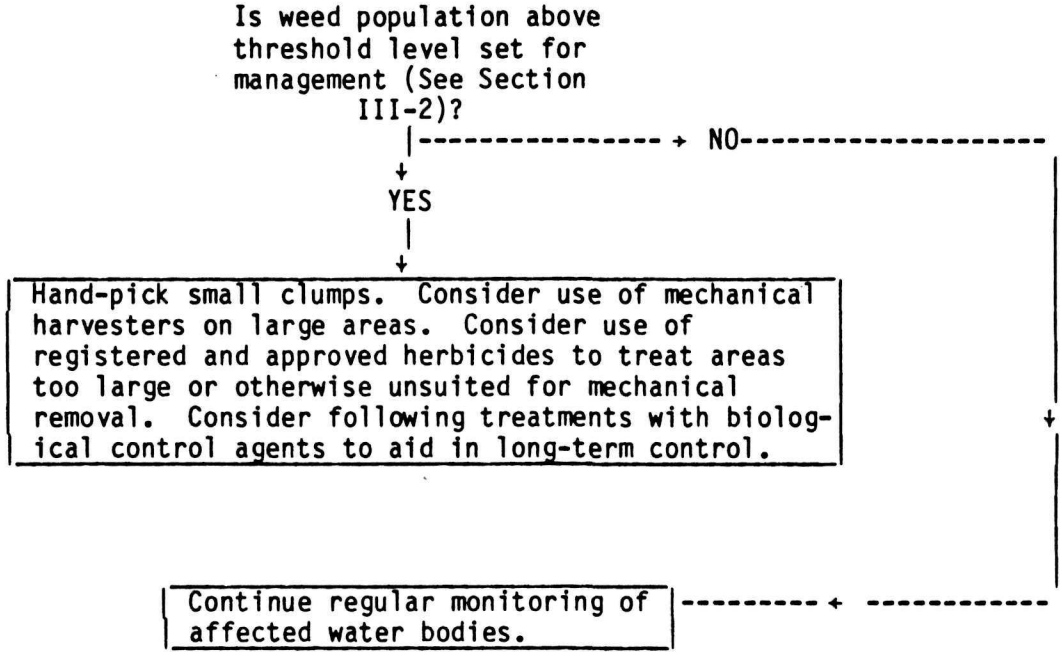
I. HYDRILLA IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




You wish to control existing hydrilla infestations
Is the infestation in a developed area or other high-use aquatic site (e.g., swimming lake)?
YES
Go to page XVIII-4.
NO
Infestation is in a natural area.
Only isolated, small-scale infestations are found.
YES
Hand-pick or otherwise mechanically remove all hydrilla from the water body. Remove all plant fragments to prevent regrowth.
NO
Actively growing infestation is found.
Are desirable species threatened by weeds?
NO
Consult your regional IPM Coordinator or local U.S. Army Corps of Engineers district for information on biological control agents. (At this time no biological control is considered suitable for use in NPS areas.)
YES
Consider spot-treating the hydrilla colony with an approved herbicide. For long-term control, consider introduction of suitable biological control agents if available. (See Section III-3.)
Continue regular monitoring of affected water bodies to determine efficacy of treatments.


Is weed population above threshold level set for management (See Section III-2)?
NO
YES
Hand-pick small clumps. Consider use of mechanical harvesters on large areas. Consider use of registered and approved herbicides to treat areas too large or otherwise unsuited for mechanical removal. Consider following treatments with biological control agents to aid in long-term control.
Continue regular monitoring of affected water bodies.

II. HYDRILLA BIOLOGY AND ECOLOGY

1. Species Described:

Hydrilla (*Hydrilla verticillata* Royle) (also known as Florida elodea) is a submerged aquatic monocot in the family Hydrocharitaceae. It grows rooted in the hydrosoil, with long stems which branch profusely near the surface and narrow pointed leaves. Stems can grow to lengths of several feet from the substrate to the surface of the water. Hydrilla is not uncommonly found growing in water 10 feet deep or deeper, and has been reported from depths of up to 50 feet in exceptionally clear water (Haller et al., 1976). Most of the biomass is found in the upper 2 feet of water column.

Hydrilla is well known to display a great amount of variability in morphology, with plants from the Potomac River near Washington, D.C. showing a different number of chromosomes than plants from Florida (Haller, 1982). The general structure of the plant consists of lower leaves opposite and small, median and upper leaves in whorls of 3-5, larger than lower leaves; 2-4 mm wide, 8-18 mm long, with sharply toothed margins, red veins and spines on the underside ribs (this feature is not apparent on preserved specimens). Leaves have a scabrous or harsh texture, which feels brittle and scratchy; foliage of the similar-appearing elodea feels smooth to the touch (Tarver et al., 1979). Flowers are small, 4-5 mm across, with 3 petals and 3 sepals which resemble petals. The entire flower is translucent. Male flowers are borne in leaf axils, contained in spathes. Female flowers are borne on stems arising from leaf axils. Flowers are borne above the water surface.

Hydrilla is considered dioecious, with only the female plant reported in the U.S. However, Vandiver et al. (1982) have reported a monoecious (male and female flowers) strain from the Potomac River in Washington, D.C. and Maryland.

Hydrilla is easily confused with elodea (*Elodea canadensis*), *Anacharis*, and *Egeria* which are all considered to be desirable plants (Haller, 1982). Any suspected infestations should be confirmed by a botanist familiar with aquatic plant species.

2. Geographic Distribution:

Hydrilla is believed to be native to Uganda and northern Tanzania, but has spread to many other regions including the southern U.S., southern Europe, the Middle East, southern Asia, central Africa, the East Indies, and Australia.

The earliest documented occurrence in the U.S. was in Dade County, Florida in 1959, probably as discarded aquarium plants. Hydrilla is currently distributed in the U.S. throughout the Southeast; in Florida, Louisiana, Texas, Georgia, South Carolina, North Carolina, Alabama, Maryland, Delaware, and the District of Columbia. Although it has not yet been reported from Virginia, hydrilla is in the Potomac River. Hydrilla infestations have also been reported in California, Iowa, and Connecticut (Haller, 1982).

3. Habitat:

Hydrilla inhabits a large variety of aquatic habitats including rivers, lakes, sinks, slow streams, ditches, pools, tidal waters, and irrigation and drainage canals. It grows particularly well in calcareous sites (Manning and Johnson, 1975).

4. Hosts:

Not applicable.

5. Life Cycle:

Hydrilla, due to its ability to grow under low light (less than 1% of full sunlight), is a superior competitor, able to begin growth in spring earlier and grow in deeper or more turbid water than most aquatic plants. Biomass production may exceed 20 tons per acre (fresh weight); hydrilla is 95% water by weight (Canellos, 1981).

Vegetative reproduction, by branch-tip fragmentation, horizontal stolons on the surface of the hydrosoil, horizontal rhizomes under the hydrosoil, overwintering buds (turions), or subsurface stem nodules (tubers), is the common form of reproduction in the U.S. Tuber formation is the most effective mode of reproduction, with 10-20 times as many tubers formed as turions.

In early spring, as the water warms and the days become longer, new shoots arise from stem fragments, tubers, and turions (overwintering buds) in the hydrosoil.

Throughout the summer, hydrilla stores starch in its stems, stolons, and underground rhizomes.

By late summer, the mat is at maximum density. Algae and small floating plants such as duckweed and Azolla often grow on the hydrilla mat and further interfere with light penetration. As the days shorten, photosynthesis decreases and respiration increases. When respiration exeeds photosynthesis, hydrilla slowly sinks to the hydrosoil, starch reserves are mobilized, and tubers are produced (in water above 50°F) until spring, when nodes, tubers, and turions germinate and start the growth cycle anew (Haller, 1978). Hydrilla in Florida flowers in fall and early spring (Haller, 1978). Elsewhere in its range, hydrilla flowers in early fall.

Tubers are protected by the hydrosoil from most adverse conditions such as ice, drought, and chemical herbicides. They are the major overwintering stage of the plant. Tubers form at a depth of 2-8 inches in the hydrosoil. Tuber size and density increases with water depth, reaching maximum size and density at about 5 feet. Peak tuber densities have been recorded at 250,000-21,800,000 per acre (Tyndall et al., 1982).

Tuber formation is induced by less than 13 hours of light per day. Tuber formation is inhibited by temperatures below 48°F in laboratory conditions (Van et al., 1978), and presumably is also inhibited in the field by low temperatures.

Turions form on floating stem fragments in leaf axils. After a 4-week development, the turion falls from the fragment and sinks to the bottom where it roots and sprouts. Turions form from April to September, and germinate throughout the spring and summer months.

6. Seasonal Abundance:

Foliage is present and grows from early spring when the water warms, to late fall when the plant sinks to the bottom. Tubers form at the ends of rhizomes from October through May in water above 50°F, and germinate in late spring through summer.

7. **Response to Environmental Factors:**

Hydrilla grows well in alkaline to slightly acid water, and equally well in oligotrophic to highly eutrophic conditions. It has been found growing in fresh and brackish water (up to 10 ppt salt) It is most prolific in hard water with a high calcium content (Rodgers et al., 1983).

It has been reported growing at depths of up to 50 feet in extremely clear water (Haller et al., 1976), but is usually found at depths of less than 15-20 feet. Hydrilla grows well in turbid water, due in part to its low light requirements.

Hydrilla fragments may be dispersed by currents, on boats or boat trailers, or by waterfowl. Stems often break loose and form floating mats of vegetation.

8. **Impact of Hydrilla:**

Hydrilla impairs multiple uses of surface waters including recreation, fishing, navigation, irrigation, and aesthetic values.

8.1 Direct Impact:

Hydrilla mats shade the bottom, preventing growth of native submergent aquatic plants. Hydrilla utilizes light more efficiently than native submersed species and rapidly grows to the surface of the water, forming a dense, entangled mat. This mat prevents light from penetrating the water to reach other submersed plants, resulting in the complete dominance of the aquatic flora by hydrilla.

Mats may foul boat propellers. Swimmers may become entangled and drown. Fishing in shallow water may be hampered. Mats afford increased cover to forage fish, causing population buildups, and stunted populations of forage fish may result due to excessive numbers of small fish and fewer predatory species.

Forage sunfish and small largemouth bass are not adversely affected until most of the water column is occupied by hydrilla. Large largemouth bass (10 inches and larger) show low condition (malnourishment) factors when hydrilla occupies 30% of the water column, due in part to decreased success in predation (Shireman and Maceina, 1981).

8.2 Indirect Impact:

Hydrilla is fed upon by numerous species of waterfowl, such as American coots and ring-necked ducks (Hardin, 1982). Mats may provide a surface for small wading birds, allowing greater foraging and increased migration survival.

9. Natural Enemies:

Natural enemies in central Africa, the supposed center of origin of hydrilla, are as yet little understood (Balciunas, 1982). However, hydrilla in Uganda is believed to be fed upon by several species of herbivorous fish and at least one species of insect (Tyndall et al., 1982). The following are species currently under investigation for importation or under study for release.

A. Insects -

1. Pyralid moths - Quarantine studies are ongoing for Parapoynx rugosalis, a moth from Asia, which has been collected from hydrilla in Panama. Studies are ongoing for P. diminutalis which was first collected in 1976 at Ft. Lauderdale, Fla. P. diminutalis is an Asian species, probably introduced with aquarium plants, which has spread as far north as Tallahassee.

   Although P. diminutalis has been reported feeding on 16 different species of aquatic plants, it prefers hydrilla.

   Heavy damage to hydrilla mats by P. diminutalis have been reported as far north in Florida as Gainesville (Buckingham, 1982).

2. Weevils - Balciunas (1982) reports several species of aquatic weevils in the genus Bagous from India, including one species which oviposits in hydrilla tubers on exposed hydrosoil. Most Bagous weevil species are extremely host specific, have short generation times (approximately 2 weeks), and immature life stages are confined on or in the plant host (Balciunas, 1982). Further research on this genus is planned in hopes of finding a suitable control agent.

B. Fungi - The fungus Fusarium roseum var. "Culmorum" is currently under investigation as a biological control agent for hydrilla. F. roseum can parasitize hydrilla under conditions of suitable water quality, inoculum quality and quantity, and temperature. A spore concentration of 2.5×10^4 to 5×10^5 conidia per ml is needed to kill hydrilla.

Conidia germinate 48 hours after settling and penetrate leaf and stem cells. Once cells are penetrated, chloroplasts clump, causing photosynthesis to cease; the plant becomes chlorotic in 3-7 days, dies, and rots. Total decay occurs over a period of 3 weeks. F. roseum causes significant decline in formation of tubers and turions (Charudattan et al., 1982). Use of this organism for biological control of hydrilla is still under investigation due to its wide host range, which may include cultivated plants.

C. Fish -

1. The grass carp or white amur (Ctenopharyngodon idella), a cyprinid, was introduced into Arkansas and Alabama in the late 1950s. It has since escaped into the Mississippi River drainage system, the Great Lakes, and probably has been introduced into every state in the U.S. (Haller, 1978). It feeds almost exclusively on aquatic plants and is under investigation for control of hydrilla, water hyacynth, and other aquatic weeds (Gangstad, 1978). Hydrilla is listed as a preferred food plant of grass carp (Hardin, 1982). While only 11 states currently permit the introduction of the grass carp, possible breeding populations appear to exist throughout the southeastern U.S., circumventing most efforts at quarantine.

   Hardin (1982) reports that hydrilla was eliminated from a large Florida lake due to feeding pressure from grass carp stocked at rates of twenty 0.5-kg fish per estimated metric ton of hydrilla (twenty 1-lb fish/ton).

   Osborne (1982) states that grass carp may not be effective as biological control agents for hydrilla, due to low feeding rates when adult size is reached.

   Attempts at breeding sterile hybrid grass carp have been limited by high mortalities from hybridization and predation. Hybrid grass carp have low growth rates and associated low feeding rates (Osborne, 1982). An additional problem associated with hybrid carp is the relatively low feeding preference for hydrilla compared to other exotic and native aquatic plants (Cassani and Caton, 1983).

2. Tilapia zillii (Grevais), an imported cichlid, has been reported to cause significant reduction of hydrilla and other problem exotic aquatic weeds in sections of the All-American and other canals in California (Legner, 1983).

D. Birds - Hardin (1982) reports American coots and ring-necked ducks feeding on hydrilla in Florida, but gives no indication of food preferences. In addition, twelve species of waterfowl including tundra swan, Canada goose, mallard, American wigeon, ruddy duck, and gadwall have been observed feeding on hydrilla in the Potomac River (Neal Fitzpatrick, personal communication).

E. Manatees - The manatee (Tricheshus manatus L.), an endangered species, is a large, slow-moving, social, roughly torpedo-shaped marine mammal. Manatees live in warm, shallow coastal waters from Texas to southern North Carolina, feeding on aquatic plants. A mature manatee can consume 60-100 lb of vegetation each day. Manatees are rare throughout their historic range.

III. HYDRILLA MANAGEMENT

1. Population Monitoring Techniques:

Hydrilla can be monitored by aerial photography. Black and white prints are the least expensive for covering large areas, but are more difficult to interpret than color. Color film has excellent water penetration capability, and is considered ideal for submerged plants. False color infrared photos provide the best contrast for submerged plants, but require narrower tolerances in developing than either color or black and white, have lower water penetration than color, and require interpretation by a trained technician (Dardeau and Hogg, 1983).

Recording fathometer surveys (Maceina and Shireman, 1980) or surveys by divers are useful in locating boundaries of hydrilla patches, as well as mat size and depth. Topographical surveys incorporating these data can then be used to map distribution of problem populations with respect to surface landmarks or buoys. Distributions should be marked on maps or photomosaics of the water body and recorded on monitoring forms in order for post-treatment surveys to be useful (Dardeau and Hogg, 1983).

Surveys from boat and shore should be conducted to complement and support data gained from aerial and/or underwater surveys. Photos incorporating recognizable landmarks and showing extent of infestation should be included in shore or boat surveys.

2. Threshold/ Action Population Levels:

As with most aquatic weeds, standardized threshold levels for hydrilla have not as yet been formulated. A unique threshold level must be established for each water body, based on considerations such as type and size of the water body, activities which occur at the site (e.g., fishing, swimming, boating), numbers and types of desirable flora and fauna inhabiting the site, and the aesthetic and/or nuisance impact of weed populations on visitors to the site. Such information can be correlated with inspection data (e.g., population levels and conditions, extent of coverage) to produce threshold and action population levels for each site. In a single area, high-use aquatic sites (swimming beaches, boat docks) will be more sensitive to hydrilla infestations than will low-use areas (wildlife preserves or shore-only fishing areas).

The U.S. Environmental Protection Agency has developed a computerized "expert system" for the determination of threshold levels and the design of programs for aquatic weed management in water bodies in several southeastern states (Rodgers et al., 1983). Use of the system requires the input of information concerning the location and type of affected water body, available water quality data, water uses, growing season data, infestation area, and the known or reported effects of the infestation on water body uses (Anonymous, 1983). The system ("Decision Matrix for Integrated Control of Aquatic Weeds") is currently usable on Apple III® computers. For information concerning the availability of the system, contact:

Charles D. Reese
Office of Pesticide Programs
U.S. Environmental Protection Agency
Washington, D.C.

3. Management Alternatives-Nonchemical:

1. Mechanical/Physical Controls

A. Harvesting includes all techniques which actually remove the target plants from the infested water body. Harvesting has been recommended under the following conditions:

1. Where shallow zones of ponds or lakes are covered by dense mats of weeds.

2. When the use of other methods is undesirable due to potential adverse impacts on water use or wildlife.

3. Where nuisance weeds are resistant to herbicides.

4. Where nutrient loading from decomposing weeds left in the water could promote eutrophic conditions.

5. In small lakes, ponds, or embayments (less than 100 acres).

Harvesting may not be beneficial where internal obstructions in the water body could impair the process, where shallow areas could be disturbed by the process, or where weed fragments could be dispersed by current or wind, compounding the weed problem (Rodgers et al., 1983).

Although cutting may serve to increase dispersal through fragmentation, McGehee (1979) contends that if areas are 80-90% infested, cutting outweighs possible acceleration of spread to remaining areas.

A disadvantage to harvesting is the possible high cost relative to chemical or biological controls, although the cost is comparable if harvesting is properly timed and if only selected areas, such as boat channels or fishing areas, are cleared (McGehee, 1979). Harvesting methods include:

1. Hand removal - Small scale infestations can be eliminated by handpicking or raking the weeds, which should then be removed to an on-shore disposal site. While this technique is somewhat labor intensive, it could be incorporated into surveys, allowing small infestations to be destroyed as soon as they are detected.

2. Mechanical harvesting - Harvesting machines usually consist of a boat- or barge-mounted cutter and collection system, which feeds cut material into a conveyor for shore dumping, may throw cut material onto the shore, or may not collect material (cutter system only). Harvesters cost between $6,000 and $170,000 (1982 basis), and are available from the following manufacturers:

   a. Aquamarine Corp.
      Box 616
      Waukesha, WI 53186

   b. Altosar Aquatic Weed Harvesters
      3147 Losey Blvd.
      LaCrosse, WI 54601

   c. Hickney Co.
      913 Cogswell Dr.
      Silver Lake, WI 53170

   d. Limnos, Ltd.
      22 Roe Ave.
      Toronto, Ontario, CANADA

   e. Mariner Water Weed Harvesters
      104 Locust St.
      Polmyra, WI 53156

f. Mudcat Division
National Car Rental Co.
P.O. Box 16247
St. Louis Park, MN 55416

Harvested hydrilla can be composted for use as mulch, or combined with other vegetation as silage for livestock feed (Bagnall et al., 1978).

B. Benthic semi-barriers - consist of closely woven screening of polyvinyl chloride-coated fiberglass, and are applied directly over rooted aquatic weeds by SCUBA divers. Semi-barriers with 62 apertures/cm^2 absorb 60% of visible light, resulting in complete elimination of weeds in about 3 weeks (Mayer, 1978). Further regrowth is limited to about 5% of the normal cover. Semi-barriers must be replaced or cleaned before silt and debris form new suitable substrate, allowing recolonization.

C. Drawdown - Drawdown refers to the periodic lowering of water levels in infested water bodies to retard weed growth by destroying plants through exposure to desiccation and/or freezing conditions. Goldsby and Sanders (1977) conclude that consecutive annual drawdowns are more effective than single drawdowns.

Drawdown has been used successfully to reduce hydrilla populations, but tubers have withstood dry conditions for up to 10 years in laboratory conditions. Drawdown can be highly disruptive to inshore or shallow water organisms, particularly if improperly timed (Lantz et al., 1965). See Haller (1978) for proposed drawdown schedules used in north Florida.

Manning and Johnson (1975) report 100% control of hydrilla using drawdown (2.7 m total fluctuation) integrated with herbicides (2,4-D and diquat) in a Louisiana lake.

For further information on mechanical/physical controls for hydrilla, contact:

U.S. Army Engineer Waterways Experiment Station
P.O. Box 631
Vicksburg, MS 39180

2. Biological Controls

At the present time, no vertebrate biological control agents are considered suitable for hydrilla control within NPS areas. Consult your regional IPM Coordinator for updated information concerning fish as biological controls of aquatic weeds.

Recommendations and caveats for stocking grass carp are as follows (from Schardt et al., 1982):

1. Grass carp feed on hydrilla in preference to most other aquatic plants.

2. Grass carp should be used only if eradication of preferred (non-weed) vegetation is tolerable. There is no control over areas in which grass carp will feed after they are placed into the system. If there is desirable vegetation in the system that is preferred by grass carp, it will eventually fall under the same pressure as the target weed species.

3. Grass carp should not be used to control nonpreferred species of vegetation when desirable preferred vegetation is present in the system. The preferred species will be consumed first, leaving open areas for the nonpreferred species to colonize.

4. Young grass carp should be stocked in concentrations large enough to result in control in 2 years. Young (smaller than 30 cm; 12 inches) grass carp eat up to 200% of their body weight in hydrilla each day. Older, larger (over 6 kg; 13 lb) grass carp eat about 25% of their body weight in weed each day (Shireman and Maceina, 1981). Juvenile grass carp will consume more total weed per day than will mature adults (a 3 kg carp can be expected to consume approximately 3 kg of hydrilla per day).

   After 2 years, grass carp mature, and feeding rates decline with age (central Florida; in more northern areas, grass carp growth rates are proportionately slower).

5. Grass carp should be stocked in early spring (after winter vegetation die-off) or after mechanical or chemical treatment (while standing crop biomass is at a minimum). Grass carp will immediately begin to reduce vegetation from base amounts present in the system. If introduced during the peak vegetative growth season, grass carp will at best be able to control new growth only. If stocked at the end of the growing season, grass carp may remain small throughout the winter and be more vulnerable to predators. Stocking rates of twenty 0.50-kg fish per estimated metric ton of hydrilla (1 lb/ton) are recommended to achieve control in 1 year.

Shireman and Maceina (1981) recommend stocking rates of 34 fish per hectare (85 fish/acre) of hydrilla or 134 kg of fish per hectare (120 lb/acre). Total control is achieved when the biomass of grass carp exceeds 185 kg per hectare (160 lb/acre) of hydrilla.

6. Additional grass carp should be stocked within 3-4 years if control is not achieved, as by that time, the original stock of carp will have matured and decreased their consumption rates, losing the ability to control heavy growths of vegetation.

As mentioned previously, grass carp are currently allowed in only 11 states; however they have expanded their range to, or have been introduced in virtually every watershed in the U.S. (Haller, 1978).

Sport or commercial fisheries may be impacted by the introduction of grass carp due to elimination of vegetative cover for forage fish and juvenile sport fish (Hardin, 1982).

Haller (1978) states that grass carp are most useful in small, isolated bodies of water such as golf course ponds, farm ponds, or similar waters. Complete control depends upon the amount of vegetation, water temperature and the number, size, and sex of the fish, and losses through predation (Osborne and Sassic, 1981).

Consult your regional IPM Coordinator before attempting any introduction of exotic species for control of hydrilla.

4. Management Alternatives - Chemical:

Several herbicides are registered by USDA for use on hydrilla (Anonymous, 1980); alone or in conjuction with mechanical or biological measures, they have been used successfully to control infestations.

Consult your regional IPM Coordinator to determine which, if any, herbicides are best suited for inclusion in your hydrilla management program.

5. Summary of Management Recommendations:

1. Determine that the pest weed in question is in fact hydrilla; if in doubt, send specimens for identification to an aquatic botanist.

2. Monitor, using aerial surveys and/or boat and shore surveys to determine the extent of the infestation. Use maps or photomosaics to plot the infestation and for comparison with post-treatment results.

3. Use mechanical and/or physical treatments such as drawdown, semi-barriers, or harvesting where conditions warrant, and where physically feasible.

4. Consider use of biological control agents if any have been approved for use in NPS and if conditions are favorable. Consult with your regional IPM Coordinator before introducing any exotic organism into the area.

5. Consider use of an approved herbicide in conjunction with biological or mechanical controls or if infestations are heavy. Consult with your regional IPM Coordinator before using herbicides.

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V. PERSONAL COMMUNICATIONS

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NATIONAL PARK SERVICE
IPM Information Package

Leaf Miners

Final Report

11 April 1985

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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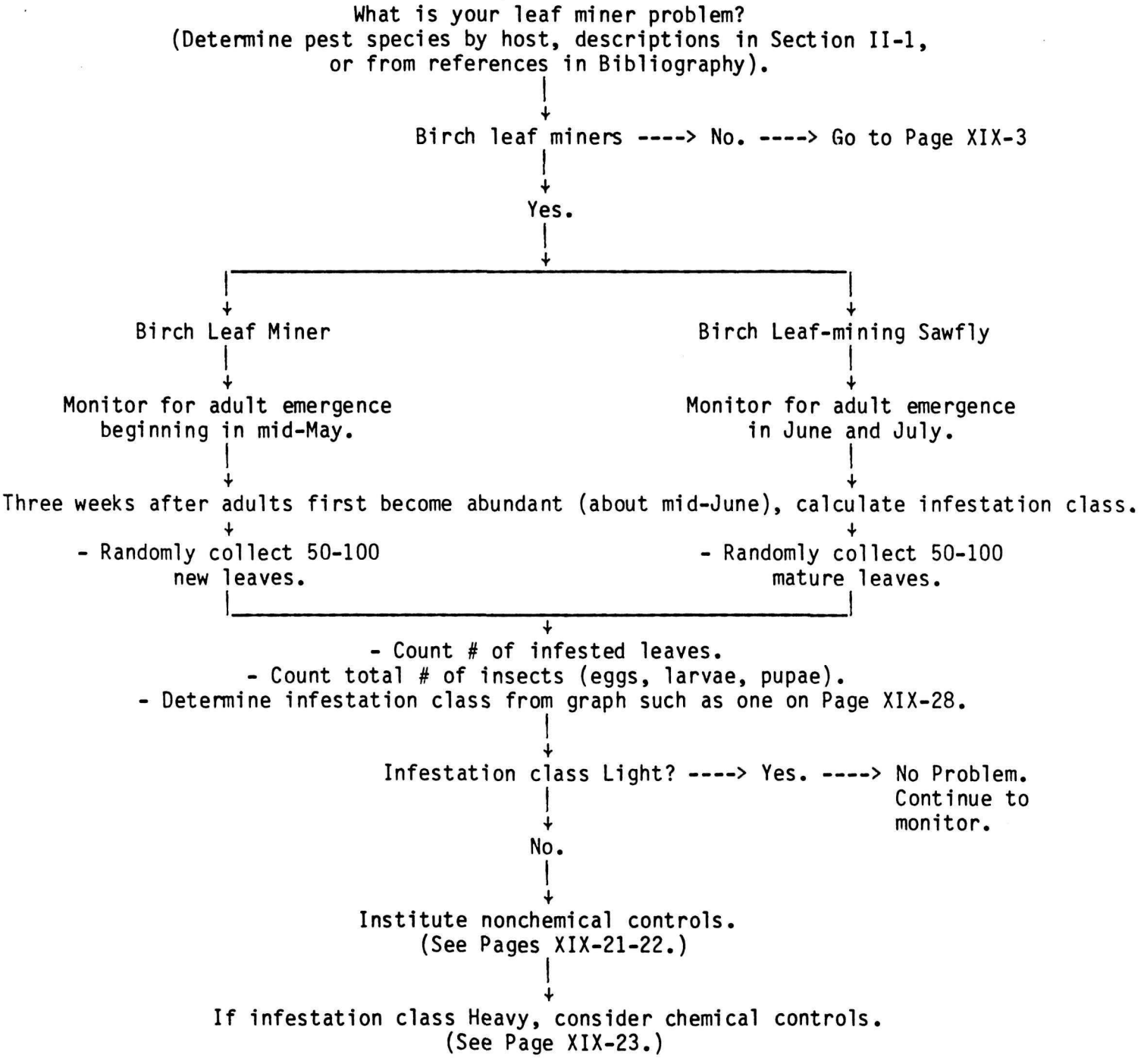
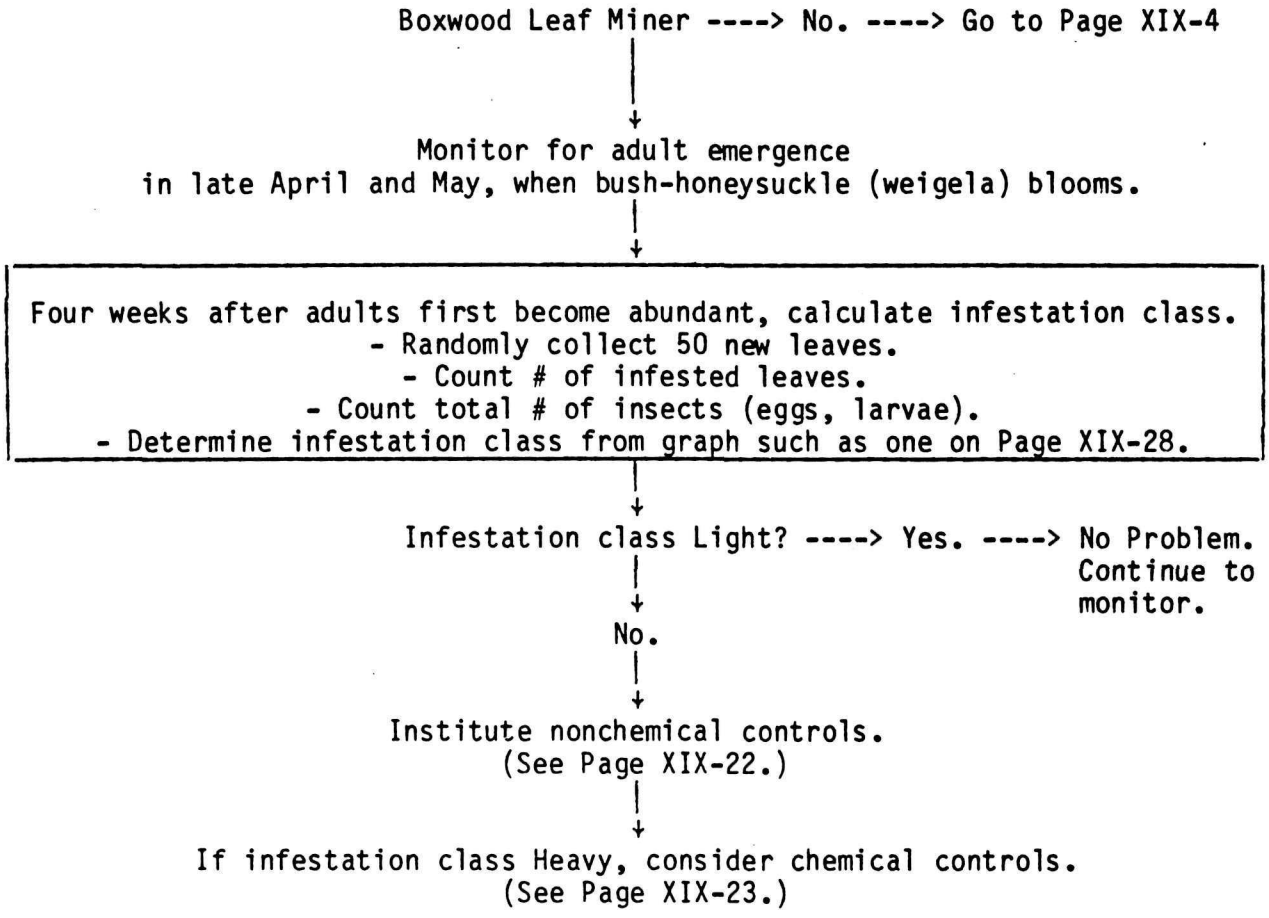
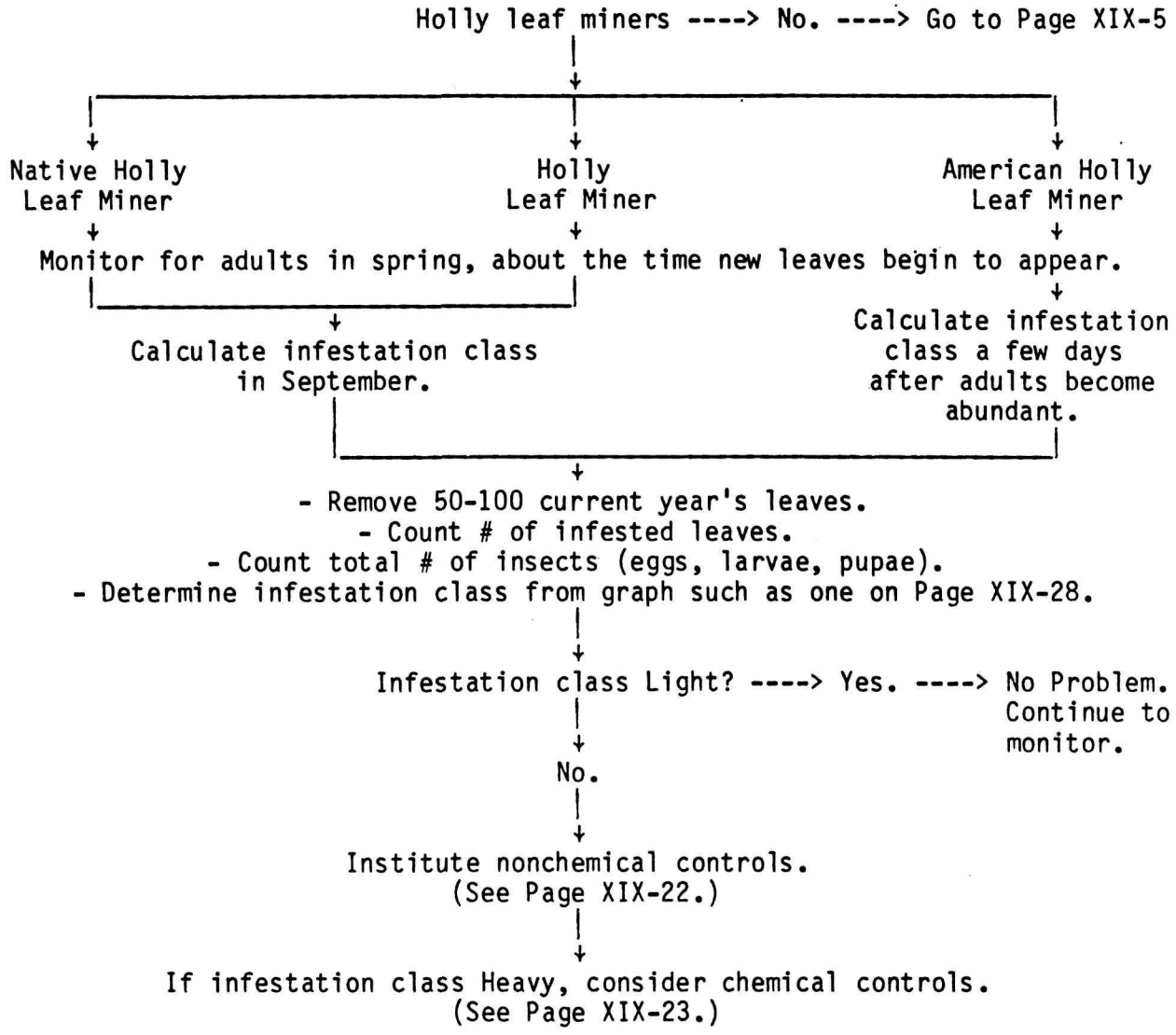
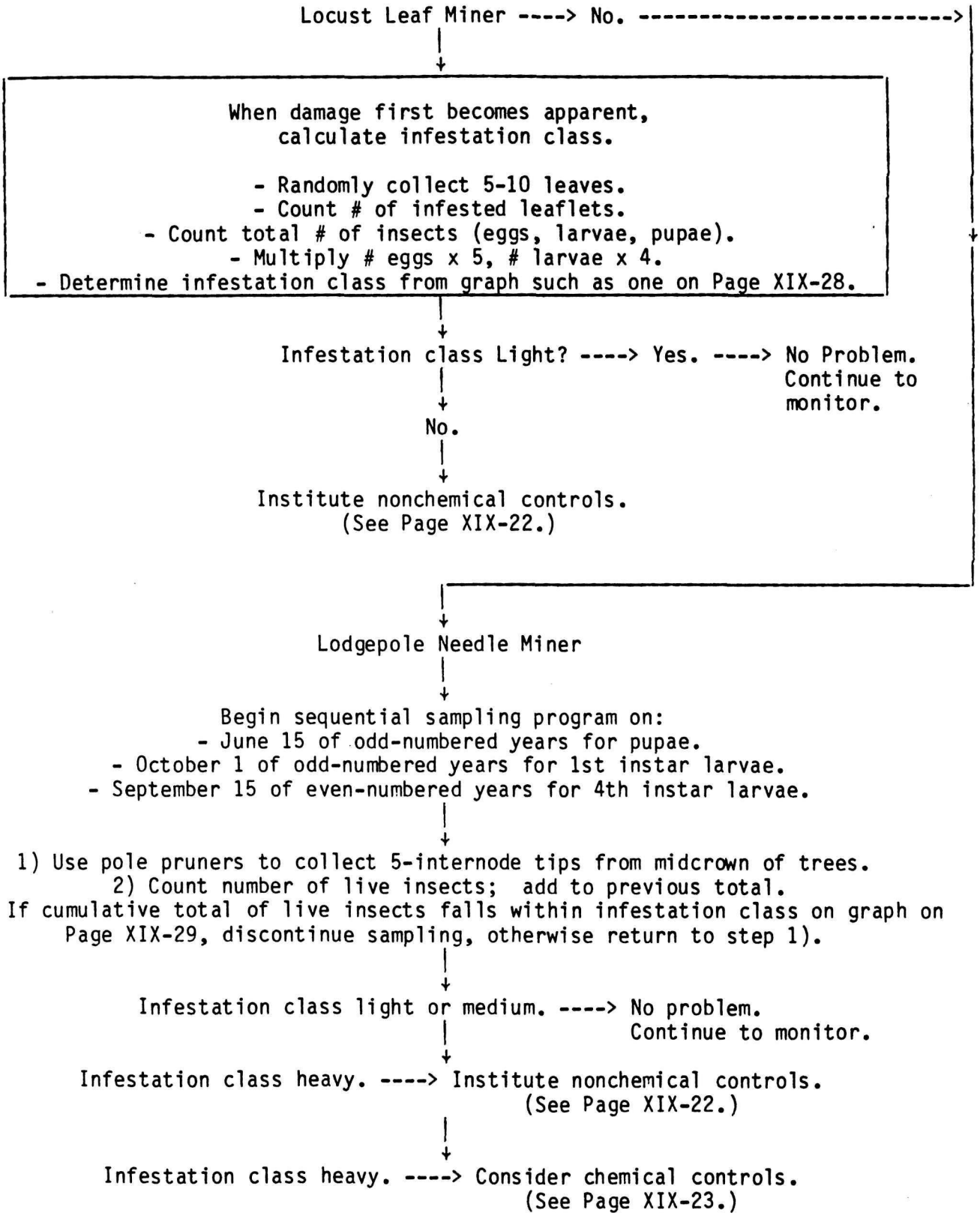
I. LEAF MINER IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




Boxwood Leaf Miner ----> No. ----> Go to Page XIX-4
Monitor for adult emergence
in late April and May, when bush-honeysuckle (weigela) blooms.
Four weeks after adults first become abundant, calculate infestation class.
- Randomly collect 50 new leaves.
- Count # of infested leaves.
- Count total # of insects (eggs, larvae).
- Determine infestation class from graph such as one on Page XIX-28.
Infestation class Light? ----> Yes. ----> No Problem. Continue to monitor.
No.
Institute nonchemical controls.
(See Page XIX-22.)
If infestation class Heavy, consider chemical controls.
(See Page XIX-23.)


Holly leaf miners ----> No. ----> Go to Page XIX-5
Native Holly Leaf Miner
Holly Leaf Miner
American Holly Leaf Miner
Monitor for adults in spring, about the time new leaves begin to appear.
Calculate infestation class in September.
Calculate infestation class a few days after adults become abundant.
- Remove 50-100 current year's leaves.
- Count # of infested leaves.
- Count total # of insects (eggs, larvae, pupae).
- Determine infestation class from graph such as one on Page XIX-28.
Infestation class Light? ----> Yes. ----> No Problem. Continue to monitor.
No.
Institute nonchemical controls. (See Page XIX-22.)
If infestation class Heavy, consider chemical controls. (See Page XIX-23.)


Locust Leaf Miner ----> No. ---------->
When damage first becomes apparent,
calculate infestation class.
- Randomly collect 5-10 leaves.
- Count # of infested leaflets.
- Count total # of insects (eggs, larvae, pupae).
- Multiply # eggs x 5, # larvae x 4.
- Determine infestation class from graph such as one on Page XIX-28.
Infestation class Light? ----> Yes. ----> No Problem.
Continue to
monitor.
No.
Institute nonchemical controls.
(See Page XIX-22.)
Lodgepole Needle Miner
Begin sequential sampling program on:
- June 15 of odd-numbered years for pupae.
- October 1 of odd-numbered years for 1st instar larvae.
- September 15 of even-numbered years for 4th instar larvae.
1) Use pole pruners to collect 5-internode tips from midcrown of trees.
2) Count number of live insects; add to previous total.
3) If cumulative total of live insects falls within infestation class on graph on Page XIX-29, discontinue sampling, otherwise return to step 1).
Infestation class light or medium. ----> No problem.
Continue to monitor.
Infestation class heavy. ----> Institute nonchemical controls.
(See Page XIX-22.)
Infestation class heavy. ----> Consider chemical controls.
(See Page XIX-23.)

II. LEAF MINER BIOLOGY AND ECOLOGY

Leaf miners are insects that live as larvae and sometimes as pupae inside the leaves of plants and feed on the soft tissues between the upper and lower surfaces. The spaces the larvae hollow out by feeding are called mines. Many species of insects, primarily in the orders Coleoptera (beetles), Lepidoptera (moths), Diptera (flies), and Hymenoptera (sawflies), mine the leaves of plants. This Information Package deals with selected species of concern to the National Park Service. Most of these leaf miners are more easily recognized on the basis of their host plant and the type of mine they make, than on the basis of structural features of the insects themselves.

1. Species Described:

A. Birch Leaf Miner (BLM) - Fenusa pusilla (Lepeletier), a sawfly of the family Tenthredinidae. The oval eggs are about 0.5 mm (1/50 inch) long. Full grown larvae are somewhat flattened, and about 6 mm (1/4 inch) long. They are yellowish-white in appearance, and, except for the first and last (5th) instars, they have distinctive black spots on the underside of the thorax and first abdominal segment. The legs are small and far apart. Larvae form a common blotch mine that contains frass (excrement). Pupae are about 4 mm (1/16 inch) long, and are white at first, changing to black as the adult develops. Adults are 3-5 mm (1/8 - 3/16 inch) in length, and black. Color photographs of larvae, mines, and adults are presented in Johnson and Lyon (1976).

Birch Leaf-mining Sawfly (BLS) - Heterarthrus nemoratus (Fallen) is similar in appearance to BLM. Eggs are oval and about 0.5 mm long. Newly hatched larvae are soft and tapering, with a broad, flat thorax. The body is whitish and the head, brownish. Tiny, useless legs project sideways from the thorax. Later-stage larvae are similar, but tend to be more yellowish and have darkened areas on the first thoracic segment. Sixth instar larvae measure 6.5-10 mm (1/4-3/8 inch) in length; the thorax is flattened and the abdomen is cylindrical. The seventh instar larvae do not feed and differ in appearance from the earlier feeding instars: the body is whitish in color, including most of the head, and is flattened throughout and measures 6-8.8 mm in length. Larvae form a single large blotch mine that does not contain frass. The pupa is 6 mm (1/4 inch) in length, and is entirely white at first, gradually developing the black coloration of the adult insect. Adult females also

are about 6 mm long, and are black with fine pale yellow or whitish markings on the head, thorax, legs, and edges of the upper side of the abdomen. Males are unknown. Descriptions and illustrations of all stages, including mines and hibernacula, are provided by Peirson and Brower (1936).

B. Boxwood Leaf Miner (BXM) - Monarthropalpus buxi (Laboulbene) is a fly of the family Cecidomyiidae. Larvae are yellowish or white, and less than 3 mm (1/8 inch) long when full grown. The body is slightly flattened, widest at about 1/4 of the distance from the head, and tapered to the rear end. The last segment of the abdomen has two minute papillae, or processes. Larvae make common mines in the undersides of leaves marked by blister-like swellings of the leaf surface. Pupae are about the same size as mature larvae, widest at the front and tapered to the rear, and are reddish brown when mature. Adults are about 2.5 mm long, and look like tiny, frail, orange-red mosquitoes. Color photographs of all stages, including mines, are presented in Johnson and Lyon (1976) and Baker (1980).

C. Holly Leaf Miners - Phytomyza species are flies of the family Agromyzidae. Seven species are recorded mining leaves of holly (Ilex spp.) in North America (Kulp 1968). Three species are of concern to the NPS: Phytomyza ilicicola Loew, the Native Holly Leaf Miner (NHLM); P. ilicis Curtis, the Holly Leaf Miner (HLM); P. opacae Kulp, the American Holly Leaf Miner (AHLM). All of them are similar, but can be distinguished by host preferences and type of mine.

Eggs are white, tapering at both ends, but slightly blunted at one end, and are 0.25 mm in length. Larvae are typical fly maggots, shaped like an elongated cone with the mouth opening at the pointed end and the anal opening and breathing holes at the blunt end. They range from colorless to yellow to pale green in color. Mature larvae measure 0.9-3.9 mm (1/64-5/64 inch) in length. NHLM larvae form mines that begin near the edge of the leaf, are narrow linear at first and widen into irregular blotches as the larvae mature. HLM larvae form small mines in the midrib

initially, then move into the blade of the leaf and form blotch mines. AHLM form linear mines in all instars, each yellow-orange mine traversing a leaf 2-3 times. Puparia are pale white or yellow at first, becoming reddish brown or black as they mature. They range from 1.6-3.0 mm (1/16-1/8 inch) in length. The adults measure 1.4-2.8 mm in length, with the females slightly larger than the males of the same species. They are grayblack in color, and the abdomen is tapered and blunt at the end. Detailed descriptions of all stages, illustrations of the mines, and keys to adults are given in Kulp (1968).

D. Locust Leaf Miner (LLM) - Xenochalepus dorsalis (Thunberg). This is a small leaf-mining leaf beetle (Chrysomelidae: Hispinae). Full grown larvae are about 9 mm (3/16 inch) long. The head and legs are black, as are large areas of the top and underside of the first thoracic segment and the tip of the abdomen; the rest of the body is yellowish white. Larvae are somewhat flattened and about the same width throughout. Abdominal segments 1-8 are cone-shaped on each side, with darkened protuberances at the tips of the cones of segments 2-8. Larvae form irregular blotch mines. The adults are about 6 mm long and slightly flattened. Their overall appearance is wedge-shaped, with a small head and pronotum and the wing covers (elytra) widening posteriorly and bluntly rounded apically. The head, antennae, and legs are black; the pronotum is orange, and the wing covers are orange except for a streak of black along the inner margin of each elytron. Each wing cover has 10 rows of indentations and three raised longitudinal ridges. A color photograph of larval mines and adults is given in Johnson and Lyon (1976), and descriptions of adults, pupae, and larvae are available in Needham et al. (1928) (as Chalepus) and Baker (1972) (as Odontota).

E. Lodgepole Needleminer (LNM) - Coleotechnites milleri (Busck) is a moth of the family Gelechiidae. Eggs are lemon yellow, ovoid, and 0.2-0.3 mm long. Larvae are usually a fairly uniform lemon yellow, but shades of orange, pink, and red also occur; the head and top of the prothorax are brown to black. Full grown larvae are about 7 mm (just over 1/4 inch) in

length. Mined needles are recognized by the small hole near the base made by the larva and the yellowish discoloration. Pupae are about 6 mm (1/4 inch) long, and darken to jet black as they mature. The face of the adults is white and the rest of the head, the thorax, and the front wings are light gray mottled by irregular darkened areas; the hind wings are dusky gray. The male abdomen is silvery gray and has hairy claspers at the end; the female abdomen is cigar-shaped, and is light gray at first, turning yellowish as the eggs mature. Body length ranges from 4 to 4.5 mm (less than 3/8 inch), and wingspread is about 12 mm (1/2 inch). Descriptions and photographs of all life stages are presented in Struble (1972).

2. Geographic Distribution:

A. BLM - This species, introduced to North America from Europe, was discovered in Connecticut in 1923, and now is widespread throughout the Northeastern States and southeastern Canada.

BLS - Introduced to North America from Europe in the late 1800's and first discovered here in Nova Scotia in 1905, this species now is widely distributed in southeastern Canada and the Northeastern States.

B. BXM - Another pest introduced from Europe, this one first was reported in the U.S. in 1910, and now is found coast to coast wherever boxwood is grown.

C. NHLM - Connecticut to Ohio, south to Tennessee and Virginia.

HLM - Introduced from Europe with imported holly, this species now is found in British Columbia, Oregon, and Washington in the West, and where its host is grown in the East.

AHLM - From New Jersey to Washington, D. C.

D. LLM - Eastern North America as far west as Missouri.

E. LNM - Cascade Mountains of Washington and Oregon, and Sierra Nevada Mountains of California.

3. Habitat:

All of the species described in this Information Package live, as larvae, inside the leaves of their host plants. Adults rarely stray far from these plants. See Hosts, below.

4. Hosts:

A. BLM and BLS - Most species of birch (Betula spp.); the BLS also occasionally attacks alder and hazlenut. Although they develop on most species of birch, they grow faster on gray birch, Betula populifolia, white birch, B. papyrifera, and European white birch, B. alba, than on other species. Females of BLM failed to oviposit in cage tests with a Korean birch, B. davurica (Fiori and Dolan 1984).

B. BXM - Boxwood, Buxus sempevirens, although English varieties are less susceptible than American varieties. Also B. microphylla and B. harlandii.

C. NHLM - American holly, Ilex opaca; also I. cumulicola, and one variety of English holly, I. aquifolia var. Shepherd.

HLM - English or Christmas holly, I. aquifolia.

AHLM - American holly; also I. cumulicola and some varieties of English holly.

D. LLM - Black locust, Robinia pseudoacacia; adults also feed on dogwood, elm, oak, beech, cherry, wisteria, hawthorn, and several herbaceous plants.

E. LNM - Lodgepole pine, Pinus contorta murrayana; occasionally on other pines and firs when larval densities are extremely high.

5. Life Cycles:

A. BLM - There are 2-4 generations each year depending on the length of the growing season. Adults begin to appear about the middle of May, when the first leaves of gray birch are fairly well developed. The adults do not feed. Females deposit eggs singly in slits cut in the central area of newly developing leaves (never in older mature leaves), and prefer the lower reaches of the tree. Each female lays about 22 eggs per day for a period of several days. A female usually lays only a few eggs in a leaf, but several females may oviposit in

the same leaf; as many as 63 eggs have been counted in one leaf, although the average is nine (Friend 1933). Eggs hatch in 6-10 days and the larvae begin to mine the leaf. At first, mines are separate and small but soon coalesce to form a single large blotch mine containing several larvae. Final instar larvae do not feed. Larvae mature in 10-15 days, cut a hole in the leaf and drop to the ground. They work their way through the leaf litter and humus, then burrow 1-2 inches into the soil and build a small silklined cell in which they pupate. Adults emerge after 2-3 weeks. Mature larvae of the final generation of the season overwinter in their underground cells, and pupate in the spring.

BLS - This species consists entirely of females and has a single generation per year. Adults emerge in June and July, and within a few hours they begin to lay eggs. Females prefer healthy mature leaves exposed to sun and air, and avoid young leaves and those in shaded and protected areas. Each female deposits a single egg in the tip of a leaf-tooth, most often in the apical 2/3 of the leaf. Females deposit from 22-67 eggs each, with egg laying lasting for about one week. Eggs hatch in 12 to 26 days, and after several hours the larvae begin to mine toward the center of the leaf. As the larvae develop they form a single large blotch mine in the leaf. Although 10 or more eggs may be deposited, rarely are more than five larvae able to mature in a single leaf, and most leaves support only two or three larvae. Larval development time varies, but generally lasts about 58 days. The 7th, nonfeeding instar makes its pupal chamber, or hibernaculum, within the mine near the center of the leaf. The hibernaculum is roughly circular and lens-shaped, and is formed from silk secreted by the larva. The silk hardens into a tough, waterproof, parchment-like substance, and the larva overwinters within its hibernaculum in the leaf on the ground. Pupation occurs during June and July, and the pupal stage lasts eight or nine days.

B. BXM - This species has a single generation per year. Adult flies emerge in late April and May during the time bush-honeysuckle (weigla) is in bloom (Baker 1980). Females lay eggs in

new leaves, leaving conspicuous punctures. The females die within hours of completing egglaying, and the larvae hatch about three weeks later. A single leaf may contain a dozen or more larvae. Larvae overwinter inside the leaves, and resume feeding in the spring. Pupation occurs in April, and the pupal stage lasts about 10-14 days.

C. NHLM - This species has one generation per year. Adult flies begin to emerge in the spring after the plant has begun to produce new leaves. Adults of both sexes feed on sap flowing from holes made in the leaves by the ovipositor of the females. About 10 days after emerging, the females begin to lay eggs, depositing them in the soft tissues on the underside of young leaves. Larvae hatch soon thereafter. Because the larvae are so small, they frequently go unnoticed until late in the year when their mines are larger. Second instar larvae begin to appear in October, and third instars by December. Some pupae appear in January, but mostly larvae overwinter and pupate in the spring.

HLM - Very similar to the NHLM, however, the females oviposit in the midrib of the leaf, and the first instar larvae remain in the midrib until September, when they move into the blade of the leaf and mine there.

AHLM - The biology of this species is largely unknown, but there probably are several generations per year; larval development from the first appearance of a mine to the appearance of adults takes only a few days. Adults first appear in late May, and also have been captured as late as August.

D. LLM - This beetle has one generation each year throughout the northern portion of its range, and two generations each year from Ohio south. Adults emerge from hibernation in the spring as the new leaves begin to unfold. They feed on the underside of the leaflets, chewing holes in young leaflets and skeletonizing older ones. Eggs are laid in groups of 3-5 each, overlapped like shingles, glued together and partially covered with frass. The first larva to hatch from a group of eggs makes a small hole in the leaflet and enters it to begin

feeding; the other larvae follow the first through this hole as they hatch. After feeding together on the mesophyll within this common mine for 2-4 days, they have eaten half or more of the leaflet. They then leave the leaflet and each larva searches out its own new leaflet and starts a new mine. As it matures, which takes about three weeks, each larva mines several leaflets. Pupation occurs within the final mine, and the pupal stage lasts 7-10 days. Adults emerge and begin feeding on the underside of leaflets until fall, when they seek sheltered places, such as in the leaf litter under the host tree or in crevices in the bark, in which to overwinter.

E. LNM - Two years are required for the LNM to complete its life cycle. Each new cycle begins in the summer of odd-numbered years. Adults begin emerging in July and continue emerging for about three weeks. Males usually begin emerging about 10 days before females. Oviposition begins about 24 hours after mating. Eggs are deposited in groups of 4-11 in the current year's growth in mines that have been vacated by third or fourth instar larvae, or in older, previously mined needles still firmly attached and green. Eggs hatch in 35-60 days, and the first instar larvae search out fresh green needles in which to overwinter. Rarely is there more than one larva per needle. Larvae resume feeding the next year and pass through the second instar and into the third within the original needle chosen by the first instar. Some third instar larvae leave the initial needle and migrate to new growth needles, while others continue to mine the first needle. All fourth instar larvae leave their needles and migrate to new growth needles. In trees with stunted needles as the result of heavy infestations, each larva may mine four or more needles. Fourth instar larvae overwinter, and resume feeding in the spring of the following (odd-numbered) year. Beginning in mid-April, the larvae molt to the fifth instar and mine one or more needles before pupating inside the final mine in mid-June. The pupal period lasts about 30 days.

6. <u>Seasonal Abundance:</u>

A. BLM - Females oviposit only in new growth, so populations decline as the number of new leaves

declines through the season, although adults are active throughout the summer.

BLS - Populations are greatest in July, but are most noticeable in August and September when the mines are large and evident. Adult activity is greatest in early summer.

B. BXM - Adult activity is restricted to a two week period in late April and May. The presence of larvae becomes progressively more obvious throughout the summer as the mines become more noticeable.

C. NHLM - Adults can be observed in the spring, but larvae are most noticeable late in the year as they mature and their mines increase in size.

HLM - See NHLM.

AHLM - Because the AHLM has multiple generations, it is most abundant late in the season.

D. LLM - Populations are largest in the summer and fall.

E. LNM - Adults emerge in July of odd-numbered years. Larval populations are greatest in the late summer or fall of odd-numbered years when first instars hatch from the eggs and migrate to new needles.

7. Responses to Environmental Factors:

A. BLM - Females oviposit only in new growth.

BLS - Dry conditions increase mortality of eggs. Early frosts may result in early leaf-drop, resulting in the death of larvae within the leaves. Prepupae that fall into moist areas suffer greater mortality than those that fall into drier areas. Adults are weak fliers and are easily carried by the wind. They are most active on sunny mornings when the air temperature is 65-85°F. On cool rainy days, or hot afternoons, they cling to the foliage and avoid movement.

B. BXM - Information is not available.

C. NHLM - This insect prefers plants in sunny,

exposed sites over those in partially shaded sites (Davidson and Holmes 1980).

HLM - Information is not available.

AHLM - Information is not available.

D. LLM - This species has one generation per year in the northern part of its range and two in the southern parts of its range, indicating that the life history is influenced by temperature or photoperiod or both.

E. LNM - Climatic changes are considered the most important natural factors regulating LNM populations (Struble 1972). Unseasonally low temperatures in late spring and early summer delay pupation and emergence. Mating and oviposition stop when air temperatures drop below 50°F, the wind speed exceeds 5 mph, or during rains. Eggs take longer to hatch and mortality is higher when temperatures are below normal. Overwintering larvae in needles above the snow line can be killed by unusually cold temperatures. In addition, wind, rain, and hail can kill larvae by dislodging infested needles.

8. Impact of Leaf Miners:

8.1 Direct Impact:

A. BLM - See BLS.

BLS - Mining removes photosynthetic material from the tree, resulting in lowered growth rates and a general loss of vigor. Trees seldom are killed; however, Peirson and Brower (1936) found an average loss of 20% annual growth of white birch as a result of heavy infestations of BLS in Maine. In addition, the amount of heart wood was increased.

B. BXM - New growth may be stunted and twigs may die as a result of infestation.

C. NHLM - Mining by the larvae removes photosynthetic material from the leaf, and feeding punctures made by the females result in holes, and twisted, stunted leaf growth. Leaves having three or more mines fall prematurely.

HLM - See NHLM.

AHLM - See NHLM.

D. LLM - Leaf-mining by the larvae and feeding by the adults destroy leaves and impair the health of the trees. Loss of most of the leaves on a tree for two or more seasons in a row may result in the death of the tree.

E. LNM - Unmined portions of infested needles, and uninfested needles in the same fascicle (group of needles) with infested needles, turn yellowish to golden within 11 months of larval attack. Needle loss is great because one infested needle can result in the entire fascicle dropping. Trees become yellowish and appear scorched within a year after infestation, and the crowns become thinner. Infested trees may lose 90% of their needles in the first generation of an outbreak. In successive generations, needles of the terminal shoots are conspicuously shorter than normal needles, and the number of new needles is lower than normal. Terminal growth is severely shortened, and tree mortality during outbreaks is extensive. Outbreaks may last as long as 20 years. Entire forests of lodgepole pines were killed in Yosemite National Park from 1953 to 1963, and others were severely damaged. Mature and overmature stands are most susceptible.

8.2 Indirect Impact:

A. BLM - Leaf discoloration caused by mining may be very unsightly. Loss of growth may be detrimental to commercial users of the trees, and the loss of leaves over consecutive seasons may weaken the trees and make them more susceptible to further damage by other insects and disease.

BLS - See BLM.

B. BXM - The ornamental value of boxwood plantings may be severely impaired.

C. NHLM - Larval mines and deformed, stunted leaves resulting from adult feeding punctures make infested plants unattractive and commercially unprofitable.

HLM, AHLM - See NHLM.

D. LLM - See 8.2.A.

E. LNM - Trees weakened by LNM attack are predisposed to attack and death by the mountain pine beetle. The "ghost forests" created by massive mortality of lodgepole pines killed as a result of attack by the LNM have become a "recreational curiosity and tourist attraction" in Yosemite National Park (Dahlsten and Dreistadt 1984).

9. Natural Enemies:

A. BLM - Four species of parasitic wasps are recorded from the BLM: Chrysocharis pallipes Gahan, Closterocerus utahensis Crawford, Derostenus fullowayi Crawford, and D. diastotae Howard. Two stink bugs (Podisus maculiventris Say and P. placidus Uhler) feed on the larvae, and an assassin bug (Sinea diadema Fabricus) feeds on the adults. In addition, Polistes pallipes Lepeleiter, a paper wasp, feeds on the BLM, and ants eat prepupae on the ground.

BLS - Prepupae in their hibernacula are susceptible to attack by fungi, although it is likely that only larvae that have been injured are normally susceptible. Several species of parasitic wasps attack the immature stages. These include Trichogramma minuta Riley and Cirrospilus flavicinctus Riley, which parasitize the eggs, Cirrospilus cinctithorax Girauld, which parasitizes both eggs and young larvae, and Agrothereutes slossonae Cushman, Epiurus indagator Creson, Alophosternum foliicola Cushman, Gelis urbanus Brues, and G. bucculatricis, all of which attack mature larvae, prepupae, and/or pupae. In addition, the following species have been introduced into the United States from Europe: Chrysocharis laricinellae (Ratzeburg), Chrysocharis sp., Phanomeris phyllotomae Muesbeck, Scambus foliae Cushman, and Tranosema pedella (Holmgren). C. laricinellae and P. phyllotomae became established and have been successful in controlling the BLS. (Most insect natural enemies of leaf miners lack common names and are not commercially available.)

There are several predators of the BLS, including mice, shrews, and birds. Birds are the most important, with some, such as chickadees, warblers, and goldfinches, feeding on larvae in mines on the tree, and others, such

as sparrows, robins, and juncos, feeding on prepupae and pupae in hibernacula on the ground. Ants eat BLS larvae they remove from mines on the trees, and prepupae and pupae they remove from hibernacula on the ground. When adult BLS are sluggish in unfavorable weather, ants attack them, also. Other predators include the adults of some parasitic wasps, ground beetles, wireworms, and lacewings.

B. BXM - Information is not available.

C. NHLM - One braconid (Opius striatriventris) and two eulophid (Closterocerus tricinctus and Pediobius lithocollectidis) wasps have been reported parasitizing this species (Kulp 1968).

HLM - Five species of parasitic wasps were imported from England and released in British Columbia in the late thirties and early fourties: Chrysocharis pubicornis (Zetterstedt) (=syma Walker), C. gemma (Walker), Cyrtogaster vulgaris Walker, Opius ilicis Nixon, and Sphegigaster flavicornis (Walker). All but the first became established (Clausen 1978).

AHLM - The following parasitic wasps were recorded from this species by Kulp (1968): Opius dimidiatus and O. striatriventris, Braconidae; Closterocerus tricinctus and Pediobius lithocollectidis, Eulophidae.

D. LLM - Weaver and Dorsey (1965) recorded 12 species of parasitic wasps from eggs, larvae, and pupae of the LLM. These species belong to the following families: Ichneumonidae, Eulophidae, Trichogrammatidae, Chalcididae, and Scelionidae. One species of eulophid, Closterocerus tricinctus (Ashmead), was found in over 50% of LLM pupae examined. These authors also recorded one vespid wasp predaceous on larvae, and an assassin bug predaceous on larvae and adults.

E. LNM - Larvae are susceptible to a granulosis virus, which has been reported to kill as much as 50% of the population in localized areas. Over 20 species of parasitic wasps were recorded by Struble (1972), as well as many predators, including mites, spiders, brown lacewings, thrips, minute pirate bugs, and flies. Several birds feed on maturing larvae and pupae, and on adults in flight.

III. LEAF MINER MANAGEMENT

1. Population Monitoring Techniques:

Record all information from monitoring efforts on a form such as the sample leaf miner monitoring form shown on Page XIX-30. An infestation index is calculated using the approach shown on Page XIX-28, and following the principles discussed on Page XIX-21.

A. BLM - The first emergence of adults is monitored beginning in mid-May by sticky traps or by sweeping the lower branches of trees with an aerial insect net. Sticky traps should be slightly larger than and about the same shape as the leaves, made of white, yellow, or light green plastic, and coated with a commercial sticky substance such as Tanglefoot®. The traps should be placed in the trees among the most actively leafing lower branches. The traps should be examined daily and the number of adults recorded; replace traps that have 10 or more adults adhering. Three weeks after the adults have appeared in large numbers, randomly pick 50 to 100 leaves off the lower branches of a tree (the larger the number of leaves sampled, the more confident you can be of the results, however, you must balance the confidence with the effort involved and the total number of trees monitored). Count the number of leaves containing eggs and larvae and the number of eggs and larvae per leaf. These are easily detected by holding the leaf up to the light. Calculate the infestation index.

BLS - Monitoring techniques are very similar to 1.A, except that there is only one generation per year, the adults emerge in June and July, and the females prefer to oviposit in mature leaves in exposed portions of the trees. If sticky traps are used, they should be dark green, similar to the darker mature leaves preferred by the BLS for oviposition, and placed among the older leaves of the tree.

2. BXM - Begin monitoring for adult emergence in late April, when bush-honeysuckle blooms. Use direct observation, insect aerial nets, or sticky traps similar in color to the new leaves. Following the appearance of the adults, examine plants regularly for signs of oviposition in the leaves. Four weeks after

peak adult emergence, larvae are monitored by examining 50 randomly chosen leaves from each plant or group of plants for the presence of mines. Calculate the infestation index.

C. NHLM - In the spring, at about the time of the emergence of the new leaves, use sticky traps similar in color with the new leaves to monitor adult emergence. In August or September, randomly select 50 of the current year's leaves from each plant or group of plants and examine them for larval mines. Calculate the infestation index.

HLM - See NHLM.

AHLM - Use the same techniques as for the NHLM, but since the AHLM is multivoltine (more than 1 generation per year), sampling for larval mines must begin within a few days of the first emergence of the adults, and continue throughout the season.

D. LLM - When damage becomes noticeable, begin quantitative monitoring by randomly selecting 5 to 10 leaves; each leaf consists of about 7-15 leaflets, and the leaflets will be the sample units. Select leaves from lower, middle, and upper reaches of the tree, using extension loppers for the higher leaves. Count the total number of eggs, larvae, and pupae. To account for the fact that larvae mine several leaflets each, multiply the number of eggs by 5 and the number of larvae by 4. Calculate the infestation index.

E. LNM - Stevens and Stark (1962) present a method for sequential sampling of LNM populations. Sequential sampling means that samples are taken and counts of larvae are added to previous counts until the results fall into one of four infestation classes (Light; Medium; Heavy; Very Heavy). Sample units are 5-year branch tips, unless infestations over a period of years have reduced the needle complement severely; in Yosemite National Park, 2-year tips are used. Samples are taken from midcrown using 12 foot pole pruners. At each site, at least 12-15 trees, distributed over an area of about 1/2 acre, are sampled. All live insects are counted, and the total from each sample is added to all previous totals from the site

until the total of live larvae falls into one of the decision classes established by Stevens and Stark (1962) (see Page XIX-29 for sequential sampling decision-making graph). Surveys begin in odd-numbered years: (1) October 1 for first instars; (2) September 15 for fourth instars; (3) June 15 for pupae.

2. Threshold/ Action Population Levels:

A-D. Control of leaf miners in natural areas is rarely necessary and normally not recommended. Aesthetic thresholds for leaf-mining insects on ornamental plants are difficult to establish. Each situation is likely to be different and will require that the pest populations be monitored and an infestation index be calculated that can be used to determine whether or not to implement control measures. A sample infestation index is shown on Page XIX-28. The values in this example are only guidelines; it is likely that for each situation encountered, the limits of the infestation classes will be different. For example, a holly bush along a path heavily used by visitors will have a lower aesthetic threshold than one growing in an area where it is viewed from many yards away. In the first case, the lines separating the infestation classes in the sample graph may have to be moved to the left, and in the second case, the lines may be moved to the right. Set threshold and action levels appropriate to each given situation. After adjusting the infestation classes to the situation, consider implementation of nonchemical control measures when the infestation class is Moderate to Heavy, and chemical control measures in critical areas when the infestation class is Heavy.

E. LNM - Struble (1972) established threshold and action levels for LNM in Yosemite National Park, but currently there are no accepted levels for LNM occuring in other environments (T. Hofacker, USFS, pers. comm.).

3. Management Alternatives - Nonchemical:

A. BLM - Weakened and stressed trees are more susceptible to attack than healthy trees. Maintain vigorous growth with sound silvicultural practices. Prune water sprouts and suckers in late summer or fall. In certain circumstances, it may be feasible to kill a

significant proportion of the pupae in the ground by tilling to a depth of 3-4 inches under an infested tree. Care must be taken to prevent damaging shallow roots, however. Parasites and predators may be encouraged by planting nectar producing flowers nearby, and predators may also be encouraged by use of food sprays to attract adults (see Rabb et al. [1976] for a review of various natural enemy augmentation methods).

BLS - Excellent control of BLS in the Northeast has been obtained through the introduction of parasitic wasps from Europe (see Page XIX-17). In ornamental plantings, adequate control may be achieved by raking and destroying leaves in the fall, eliminating the pupae.

B. BXM - Prune infested tips in the spring before emergence, and collect and destroy all pruned tips. Where possible, plant resistant English varieties.

C. NHLM - Plant holly in partial shade, as trees in full sun are more heavily infested (Davidson and Holmes 1980). In light infestations, control may be achieved by removing and destroying infested leaves; heavily infested plants should be pruned to remove damaged growth and the prunings destroyed to reduce NHLM populations. Encourage parasites (e.g., by spot treatments of infested trees, planting of nectar sources for adults); their presence can be determined by closely examining the leaves for exit holes made by the adults. These are almost perfectly round, in comparison with "hatch door" exit holes made by the flies (Carol DiSalvo, NCR, NPS, pers. comm.).

HLM - See NHLM. Parasites imported from England became established in British Columbia and may have contributed to control of HLM in some instances (Clausen 1978).

AHLM - See NHLM.

D. LLM - Maintain health and vigor of trees. Rake ground under trees to remove litter and reduce the overwintering habitat of the adult beetles. Encourage parasites and predators.

E. LNM - Use good silvicultural practices to maintain good stand vigor. Be alert for refugial populations of LNM in protected watersheds which can serve as a source of reinfestation during outbreaks. Predators and parasites have little effect on LNM populations during outbreaks, but may help to keep populations in check in nonoutbreak years.

4. Management Alternatives - Chemical:

A. BLM - Carbaryl and malathion are recommended as ground sprays. In addition, carbaryl is used as a foliage spray. Apply chemicals when thresholds have been exceeded.

BLS - None are registered.

B. BXM - Diazinon and malathion may be applied against the young larvae, but are ineffective against older larvae, or may be used against the adults when emergence is at its peak.

C. NHLM, HLM, AHLM - Diazinon may be applied when larval damage is evident. Do not spray adults, as this will kill the parasites which are present at the same time (J. A. Davidson, U. Md. Coop. Ext. Ser., pers. com.).

D. LLM - None are registered.

E. LNM - At present, no chemical or nonchemical controls are recommended for LNM (T. Hofacker, USFS, pers. comm.).

Refer to Hamel (1983) and Schwartz (1982) for details of formulation and application rates. Contact your regional IPM coordinator to determine which, if any, pesticide is best-suited for your leaf miner management problems.

5. Summary of Management Recommendations:

A. BLM - Use sticky traps or nets to monitor adults beginning in mid-May. Examine 50-100 leaves for eggs and larvae. Calculate the infestation index.

Maintain trees in healthy, vigorous condition. Prune water sprouts. If infestation class is Moderate to Heavy, till ground under tree to depth of 3-4 inches to kill pupae in ground; encourage parasites and predators; consider

planting resistant species.

If infestation class is Heavy, consider use of carbaryl, or other registered pesticides, to be applied at the peak of adult activity.

BLS - Use sticky traps or nets to monitor adults beginning in mid-May. Examine 100 leaves for eggs, larvae, or hibernacula. Calculate the infestation index.

Maintain trees in healthy, vigorous condition. Rake and destroy fallen leaves. If infestation class is Moderate or Heavy, consider release of parasites. Consult with your local IPM coordinator before releasing any parasites.

B. BXM - Monitor adult emergence beginning in mid-April. Monitor larvae by examining 50 leaves for presence of mines or insects. Calculate infestation index.

Prune infested plants. Consider use of English varieties that are more resistant than American varieties.

Consider use of malathion or other registered pesticides.

C. NHLM - Monitor for adults in spring with sticky traps. Monitor larval activity by examining 50 leaves. Calculate infestation index.

Remove infested leaves if not too numerous. Prune heavily infested plants. Plant new holly in partial shade. Encourage parasites.

Consider use of diazinon or other registered pesticide against larvae.

HLM - See NHLM. Consider release of parasites.

AHLM - See NHLM.

D. LLM - Examine 50 leaves for presence of mines. Calculate infestation index.

Maintain health and vigor of trees. Rake under trees to reduce overwintering habitat of adults. Encourage parasites and predators.

E. LNM - Use sequential sampling strategy to determine infestation level. Scout out refugial populations.

Use good silvicultural practices to maintain stand vigor and reduce susceptibility to attack.

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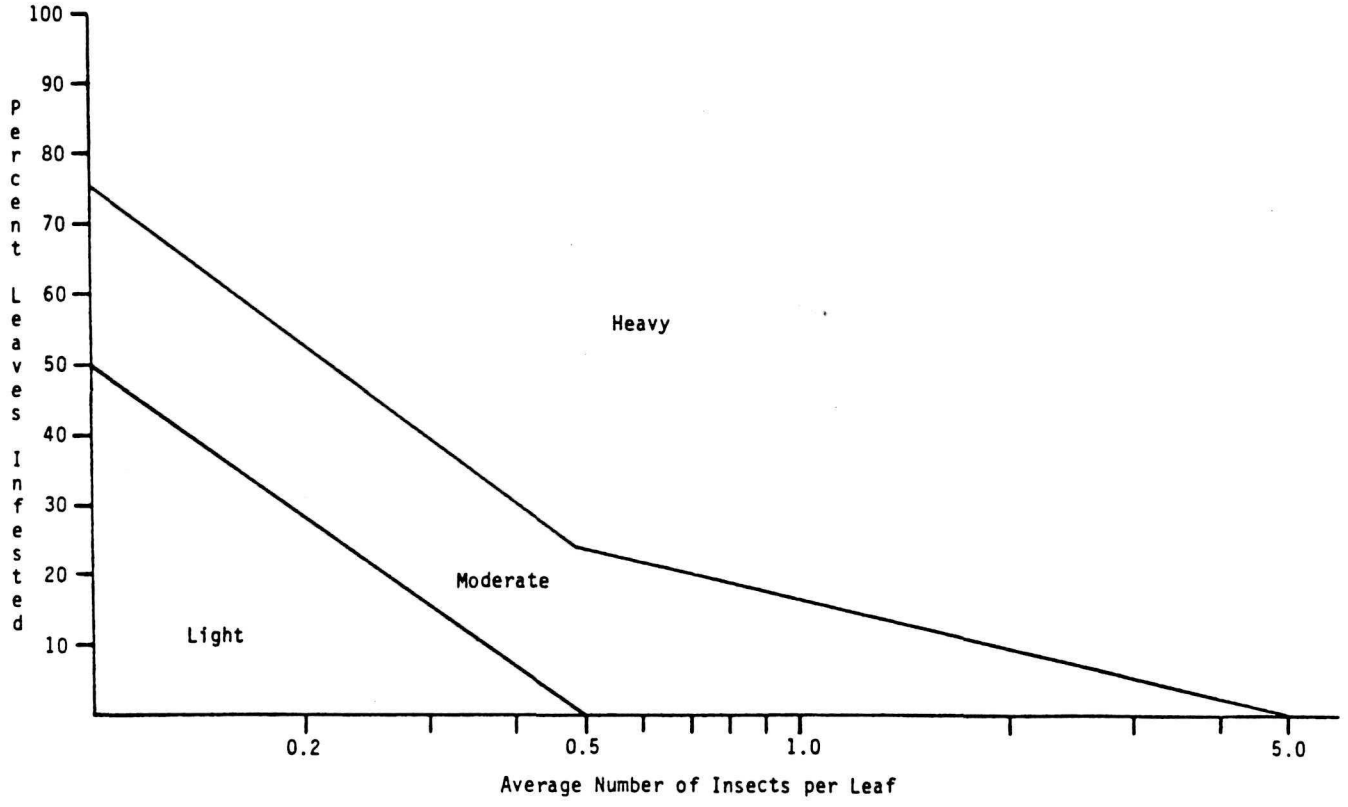
V. PERSONAL COMMUNICATIONS

John A. Davidson, Extension Entomologist, Department of Entomology, University of Maryland, College Park, Maryland. Tele. (301) 454-7121.

Carol DiSalvo, IPM Assistant, Center for Urban Ecology, National Park Service, National Capitol Region, Washington, D.C. Tele. (202) 342-1443.

Tom Hofacker, Entomologist, Forest Pest Management, US Forest Service, Washington, D.C. Tele. (202) 235-1554.

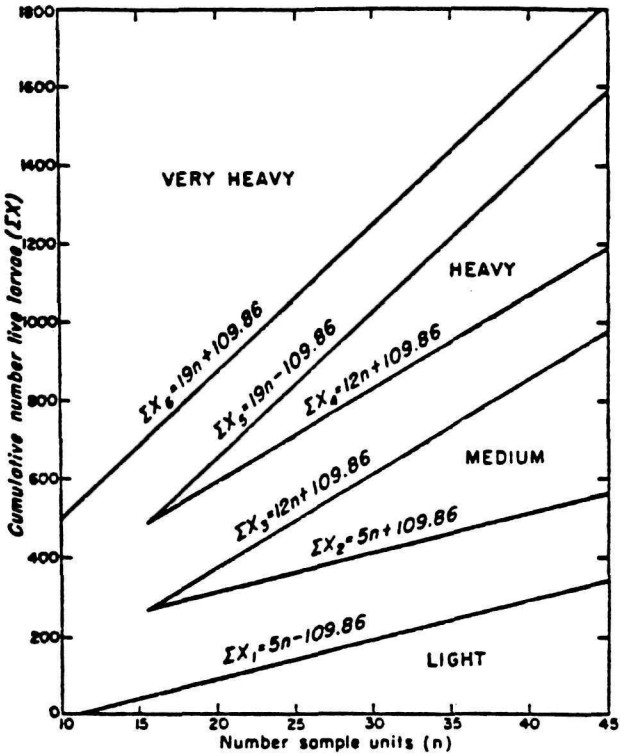
Sample Leaf Miner Infestation Index Graph



This graph was developed by setting tentative aesthetic standards for ornamental plants, based on the subjective opinions of the authors. Three levels of infestation were established; Light, Moderate, and Heavy. The index is designed to take into account the fact that leaves may have more than one larva each. To use, randomly remove 50 to 100 leaves from a plant, and count the number of leaves having live, unparasitized eggs, larvae, and/or pupae. Determine the percent leaves infested by dividing the number of leaves infested by the total number of leaves sampled, and determine the average number of insects per leaf by dividing the total number of insects counted by the total number of leaves sampled. Find the intersection of these two values on the graph and determine the infestation class. If the infestation class is Light, no action is required. If the infestation class is Moderate, nonchemical methods of control should be considered. If the infestation class is Heavy, chemical controls may be necessary.

The values used here are preliminary, and should only be used as guidelines to help establish more precise class limits appropriate to each pest and each park's particular ornamental leaf miner problems. Accurate records of levels of infestation, effectiveness of parasites, visitor awareness of leaf miner activity, efficacy of chemical and nonchemical control methods, ets., are essential to refining these preliminary values.

Sequential sampling lines for LNM (from Stevens and Stark 1962).



The sample unit used is a 2- to 5-internode tip taken from midcrown. All live insects are counted, and the total for each sample unit is added to the total of all previous sample units. Sampling continues until the cumulative number of live larvae (or pupae) falls within one of the four infestation classes. See Pages XIX-20 to XIX-21 and Stevens and Stark (1962) for more details.

SAMPLE LEAF MINER MONITORING FORM.

PARK: _____

MONITOR: _____

PLANT SPECIES: _____

PLANT MAP NUMBER: _____ (MAP AND COMMENTS ON BACK)

ADULT MONITORING- STICKY BOARD

DATE	#ADULTS	#PARASITES	INFESTATION CLASS

LARVAL/PUPAL MONITORING - LEAF MINE COUNT

DATE	#PUPAE	#LARVAE	#LARVAE/PUPAE PARASITIZED	INFESTATION CLASS	AVERAGE # MINES/LEAF

NATIONAL PARK SERVICE
IPM Information Package

LEAFY SPURGE

Final Report

30 November 1984

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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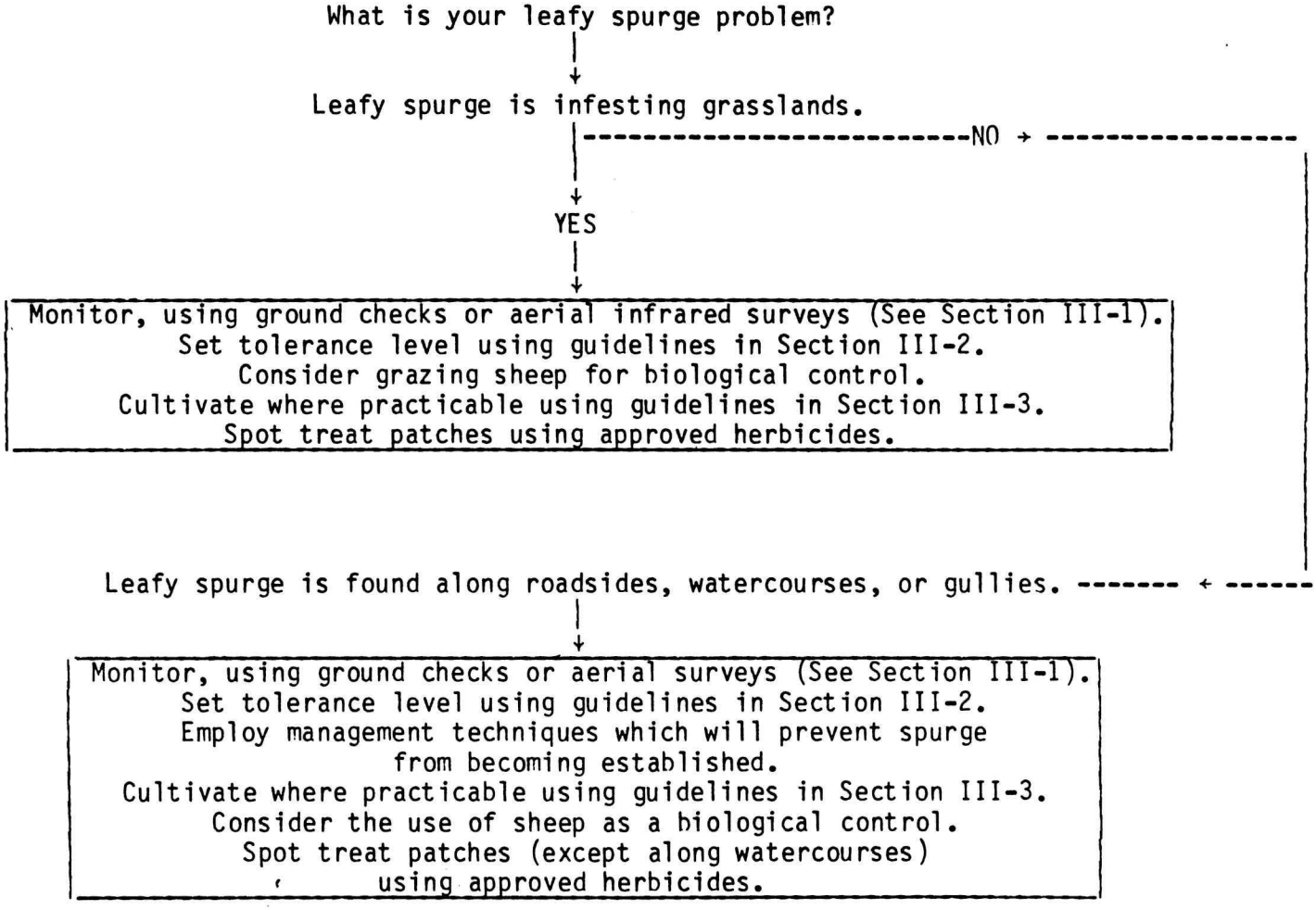
I. LEAFY SPURGE IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. LEAFY SPURGE BIOLOGY AND ECOLOGY

1. Species Described:

Leafy Spurge (*Euphorbia esula* L. of most authors) is a member of the family Euphorbiaceae. It is an herbaceous, deep-rooted perennial broadleaf plant (dicot).

Stems are 16-32 inches tall, unbranched except for flowering heads (umbels). Auxiliary branches may develop when the stem tip is injured. The stem is woody at the base. It is pale green in summer, yellow to red in fall.

Roots commonly extend 12-15 feet into the soil, and may extend into the soil for 30 feet (R. Lorenz, personal communication). Roots are covered with dormant buds, each capable of sprouting and regenerating an entire new stem from almost any depth in the soil when conditions permit. Roots and buds may remain dormant in the soil for 10 or more years (R. Lorenz personal communication).

Leaves are alternate, linear-lanceolate to ovate. They are broader above the middle, tapering to the base. Leaves are sessile (attached directly to the main stem), with entire (smooth-edged) or slightly serrate (saw-toothed) margins. They are blue-green and weakly veined, except at the midrib.

Flowers are borne on an umbel (a flowering head, similar to the flowers of the carrot) at the tip of the stem or on lateral branches near the top of the stem. Flowers are enclosed by prominent yellowish-green bracts (modified leaves which function as petals) forming clusters at the umbel.

Seeds are silvery gray, tinged with purple. The narrow end has a prominent yellow caruncle (a swelling near the scar formed where the seed was attached to the pod) with a longitudinal brown line running through the caruncle to the opposite end of the seed.

See Messersmith (1983) and Eberlein et al. (1982) for complete descriptions and photographs of leafy spurge.

Some controversy exists as to the exact taxonomy of leafy spurge. A wide range of biotypes and phenotypes exists in North America. Over 14 taxonomic names have been given to North American leafy spurge. This wide range of types helps to explain the discrepancies in the literature as to

the effect of control measures. The extreme plasticity and genetic diversity of this plant has led several researchers to believe that the leafy spurge of North America is a hybrid between 2 or more Old World spurges including E. esula, E. virgata, E. cyparissias, and E. uralensis as well as crosses between hybrids (Schaeffer and Gerhardt, 1984). The difficulty of establishing natural enemies collected from E. esula in the Old World tends to support this theory (Harris, 1979). Harris (1979) states that in the Flora of the USSR, Canadian leafy spurge specimens key out as E. virgata, not E. esula.

2. Geographic Distribution:

Leafy spurge was introduced into eastern North America from the Old World in the early 19th century. Other introductions were made in the mid-western U.S. in the late 19th century, probably as contaminants in seed grain (Messersmith and Lym, 1983a). Many reintroductions and crosses have occured in other areas and at other times, resulting in a highly diverse and complex population throughout North America (Lorenz and Messersmith, 1981). Leafy spurge infests over 1.2 million hectares of grassland in the U.S. (Sun, 1981).

The Caucasus region of the USSR is the center of distribution of leafy spurge. It occurs throughout the Eurasian continent from Norway, England, and Portugal through Asia Minor; Turkey, Iran, Afghanistan, and Pakistan. It occurs as far north as Siberia, and as far east as China (Noble et al., 1979). In Eurasia, leafy spurge is an uncommon weed of waste places due to control by over 100 species of natural enemies (R. Lorenz, personal communication).

Leafy spurge is commonly found in Minnesota, North Dakota, South Dakota, Wyoming, Nebraska, Montana, Idaho, and parts of northern Colorado, Nevada, and Utah. It is uncommonly found in scattered locations in other states, and has been reported as far south as Arizona, Delaware, and West Virginia (Noble et al., 1979). It is also common in Saskatchewan, Manitoba, and Alberta, Canada. See Messersmith and Lym (1983a) for detailed range maps.

3. Habitat:

Leafy spurge primarily is a weed of disturbed lands. Pastures and fields left fallow for long periods, tree rows, waste areas, roadsides, and rangelands or open grasslands are all susceptible

to infestations by leafy spurge. Leafy spurge is also found commonly along railroad right of ways, water courses, and gullies. It is sometimes found in cultivated lands where infested land has been broken for crop production. It is rare in fields which have been under cultivation for several years, but long-lived roots can regenerate at any time.

Leafy spurge grows on all soils from silty loam bottomlands to bare rock. It can grow on slopes as great as 40° (R. Lorenz, personal communication).

4. Hosts:

Not applicable.

5. Life Cycle:

Germination from overwintered seed is in early May. True leaves appear 6-10 days after germination (the first pair of true leaves are opposite, later, all leaves are alternate). Stem elongation and vegetative growth occur in mid-May.

Yellow bracts form in late May, with maximum display from early to mid-June.

Flower development is through mid-June, with pollen formed within 48 hours of development of each flower. Leafy spurge is pollinated by insects (Batra, 1983). The first fully developed seeds occur in early July. Seeds are borne in groups of 3 within each pod.

Seed dispersal is in mid-July, during hot, dry weather. Pods burst violently (explosively dehisce) much in the same manner as do the pods of jewel weed, scattering seeds up to 5 m (15 ft.) away from the parent plant.

Leaf loss and late summer dormancy occur during late July to mid-September. Plants releaf in mid-September with the advent of cooler weather. Several leafy branches are formed off the main stem which remains leafless. During this period, photosynthesis resumes, and additional photosynthates are transported to the root system for storage through spring.

Leafy spurge produces vegetative stems from existing roots in late April, making leafy spurge one of the first plants to emerge in spring. Early and rapid growth gives leafy spurge a competitive advantage over most crop and pasture plants.

The root system is extensive, and consists of numerous coarse and fine roots which occupy a large volume of soil. Roots are most abundant in the upper foot of soil, but some roots can extend to a depth of 30 feet. The roots are woody and tough in structure with numerous buds capable of producing new shoots. Roots may be as large as 1/2 inch in diameter in the upper foot of soil, decreasing in size with increasing depth.

The root system contains a large nutrient reserve capable of sustaining the plant for years. Root fragments as small as 1/2 inch long can give rise to new plants. Leafy spurge can withstand repeated mowing and cultivation (Eberlein et al., 1982), due to its well developed food storage system in the roots. Roots have the ability to regenerate plants from almost any depth (R. Lorenz, personal communication).

6. Seasonal Abundance:

Leafy spurge usually forms patches which may reach a density of over 200 stems per square yard in sandy soils and higher in heavy clay soils. Patches of leafy spurge usually spread vegetatively with allelopathic chemicals secreted by the root to reduce competition from 1-3 feet per year and form dense patches which crowd out other plants (Eberein et al., 1982). Plants emerge in April (from root stocks) or May (from seed) and persist throughout the growing season. Patches also expand by seed, particularly on the periphery.

7. Responses to Environmental Factors:

Leafy spurge, like all weeds capable of colonizing new areas, possesses a great tolerance for soil disturbance and partial defoliation. Seeds may remain viable in the soil for several years until conditions favor germination. Roots are capable of regeneration for many years if the leaves and stem are continuously destroyed. Leafy spurge sprouts earlier than most of the species it displaces, and can grow under a wide range of conditions.

8. Impact of Leafy Spurge

8.1 Direct Impact:

The single greatest direct impact of leafy spurge is the reduction of populations of native grasses and legumes and associated ecosystem changes caused by the superior competitive abilities (rapid growth, and allelopathic properties) of this species (Steenhagen and Zimdahl, 1979).

8.2 Indirect Impact:

Indirect impacts of leafy spurge infestations include the loss of food sources for grazing animals caused by competition with native plants in pastures and on rangeland. Spurge infestations may cut pasture production by 50-75%. Since wildlife and cattle generally avoid grazing in infested areas, carrying capacity may be reduced by up to 75% (Lacey et al., 1984). Leafy spurge is toxic to most grazing mammals, and the milky latex may cause dermatitis if ingested in small quantities by cattle or wildlife. The latex contains esters of cocarcinogenic diterpene irritants and a related antileukemic diterpenoid diester (Ratra, 1984).

A second indirect impact of leafy spurge is the cost of attemped control; in some cases, the cost of control may exeed the original cost of the land (Lavigne, 1984). Due to the extremely deep and hardy root system, leafy spurge control in uncultivated areas is costly and control measures must take place continuously over several years. Leafy spurge often regenerates when controls are eased (R. Lorenz, personal communication).

9. Natural Enemies:

No native species of herbivore is known to feed exclusively on leafy spurge. Sheep may graze on leafy spurge without ill effects (Landgraf et al., 1984). Dried spurge may be eaten in hay by stock without ill effects (Messersmith, 1982).

Natural enemies of E. esula in Europe and Asia have been introduced in the U.S. and Canada with somewhat inconclusive results. It is thought that hybridization with other introduced spurge species and other factors have changed the genotype of the North American spurge so that most natural enemies from its area of origin have had to date, inconclusive results for leafy spurge control.

III. LEAFY SPURGE MANAGEMENT

1. Population Monitoring Techniques:

While leafy spurge is present throughout the growing season, it is most conspicuous when the yellow-green flower-like bracts are open in late May to mid-June.

Leafy spurge usually occurs in patches. To monitor, count or estimate the number of patches per unit area (acre, hectare, etc.). Calculate the average patch size, and count the number of plants per square yard or meter in sample patches. This will give a fairly accurate estimate of the number of plants per area. Careful records should be kept in order to build up a profile of infestation patterns, rates, and treatments.

Leafy spurge can be monitored by aerial infared imagery using the following:

Film: Kodak 1443 color infared (for mapping purposes, use large format 9x9 2443 film)

Filter: Yellow #12

Film Scale: 1:24,000 or larger

Date: 2nd week of June - 2nd week of July

Phenology: Leafy spurge should be in full "bloom" (bract display) and growing vigorously.

The image on false color infared film will be hot pink which is characteristic of leafy spurge at full bloom and not easily confused with any other plant. Patches as small as 10x10 feet (100 sq. ft.) are easily identified using this method. See Armstrong (1979) for futher details.

2. Threshold/ Action Population Levels:

Economic thresholds for leafy spurge have not yet been developed. While it is known that heavy infestations can lower range productivity, the cost of mechanical and chemical controls are often considered to be uneconomical in most of the affected areas (Sun, 1981). Most ranchers consider spurge to be below injury level (i.e. "under control") if spurge patches do not expand from year to year (R. Lorenz, personal communication). Thresholds will differ at different sites; heavily visited park lands such as historical or developed sites will have a lower tolerance than will natural areas or grasslands.

In natural areas within the park, leafy spurge management should begin when an infestation is discovered. In areas such as historic or developed sites, or where park lands are adjacent to private or public grazing lands, management techniques should be employed to prevent spurge infestations, and established patches should be controlled to prevent spreading.

3. Management Alternatives-Nonchemical:

A. Biological control - Leafy spurge is attacked in North America by only a few generalist (polyphagus) native herbivorous insects (Harris, 1979).

1. Insects -

Several species of insect herbivores have been screened and/or introduced into North America as possible biological control agents. No single species is likely to achieve complete control throughout the range of leafy spurge, but several species may complement each other to reduce spurge population levels.

The spurge hawk moth, Hyles euphorbiae (L.), (family Sphingidae), was introduced into Canada in 1977 (Forwood and McCarty, 1980). Populations stabilized at densities considered too low to provide effective control, however, and eventually declined to extinction. Subsequent introductions in Montana and New York have become established and introductions are now planned for other states (L. Andres, personal communication). The spurge hawk moth has one generation per year; caterpillars defoliate plants once and go into diapause. Leafy spurge foliage regenerates in most instances (S. Batra, personal communication).

The moth Chamaesphecia tenthrediniformis (Denis & Schiff) was released in Canada in 1970 after promising results in feeding tests. However, all larvae released in the field died without feeding on leafy spurge. In a similar release in Australia, it was observed that the larvae of this moth fed on E. esula, but not on E. virgata (Harris, 1979). A second introduction, using another strain imported from eastern Europe, and which is highly specific to some varieties of leafy spurge thought to be present in North America, is planned for 1985 (L. Andres, personal communication).

Negative results were obtained in Canada following the release of the aphid Acrythosiphum neerlandicum which is only known from E. esula in Europe. Individuals of this species failed to develop and died on Canadian leafy spurge (Harris, 1979). Two other aphids, Acyrthosiphon cyparissiae (Koch) and Aphis euphorbiae (Kltb.), are currently under quarantine in Canada. A. cyparissiae feeds on leaves of leafy and cypress spurge; A. euphorbiae feeds mainly on stems (McClay and Harris, 1984).

The root-boring cerambycid beetle Oberea erythrocephala (Schrank), which attacks both E. esula and E. virgata, is undergoing testing in Canada and holds much promise as a possible biological control agent. This species was released in 1980 and 1982 in Wyoming using stock imported from southern Europe, but failed to establish (Harris, 1979). A second release, using new material from eastern Europe collected from a different form of spurge, was attempted in Montana in 1983. Individuals from this release established and were recovered in 1984 (L. Andres, personal communication).

The cecidomyiid gall midge Bayeria capitigena, which forms galls over the branch tips, slowing growth, stunting the plant, and preventing blossoming, has been evaluated and should be available for release in 1985 (L. Andres, personal communication). This species has several generations per year, making it an excellent potential biological control agent.

The flea beetle Aphthona flava Guill. will be available for release in 1985. The adults feed on the leaves of leafy spurge, causing minor damage, but larvae feed heavily upon the roots, stunting and eventually killing the plant. There is one generation per year (L. Andres, personal communication). This species has been successfully overwintered in Canada (McClay and Harris, 1984).

Lobesia euphorbiana, a tortricid moth which feeds within and kills the shoot tips of its host plants, is undergoing studies in quarantine in Albany, Ca. It is currently believed that the host range of this species is too broad to recommend its release in the U.S. (Pemberton, 1984).

2. Grazing by sheep -

Although grazing by livestock has not been recommended in the past, Landgraf et al. (1984) have found that sheep may graze on leafy spurge without ill effects. The diet of sheep can contain up to 50% leafy spurge with no significant difference in weight gain compared to sheep feeding in spurge-free pastures. They conclude that sheep are a viable biological control agent for leafy spurge. Pastures grazed by sheep from May to September for 5 successive seasons show up to 98% reduction in spurge populations. Utilization of and effects of leafy spurge on lambs and lactating ewes has not yet been quantified.

Grazing by sheep may not be an appropriate control measure in natural areas. Some varieties of spurge may be rejected by sheep, and in most cases spurge will regenerate the season after grazing pressure ceases (R. Lorenz, personal communication).

If sheep are to be used as a biological control for leafy spurge, the following guidelines from Lacey et al. (1984) should be followed:

1. Grazing should begin in the spring when spurge plants are only a few inches tall.

2. Schedule sheep grazing rotations so that spurge does not go to seed.

3. If sheep graze after seed set, animals should be held for 5 days to allow viable seeds to be passed before sheep are moved to new pastures.

4. Sheep grazing can be combined with herbicide use around the fringes of patches for optimal control.

3. Pathogens -

Several plant pathogens including rust fungi, powdery mildews, soil borne fungi, and foliar pathogens have been tested. To date, none have been found to be desirable control agents due to wide host ranges (which include domestic crops) or lack of permant control. Several rusts and Alternaria species have been collected recently in Europe and are undergoing testing at this time (Littlefield, 1984).

B. Mechanical control - Use of controlled burning has been attempted in North Dakota and in Wyoming. Although burning has little effect on established plants with deep root systems, fire may be highly effective in reducing seed and seedling viability. Controlled burns in the fall against the wind (burning against the wind results in more complete combustion and hotter fires), resulted in germination rates 90% lower than in unburned plots (A. Bjugstad, personal communication). Further tests using fire as a management tool, including spring burning to destroy seedlings, are planned for 1985.

Mowing, especially when used prior to treatments with herbicides, may allow reduced rates of chemicals to provide effective shoot control (Ferrell and Alley, 1984b).

Hand pulling of leafy spurge while in the bloom stage results in reduced regrowth vigor for 2 years. Pulling also damages the root, increasing the chance of infection by pathogenic organisms (Maxwell et al., 1984).

Intensive cultivation at 2-3 week intervals will reduce leafy spurge stands by 90% in the first year, and give complete control in 2 years. Similar results have been achieved by cultivation with a duckfoot cultivator every 2-3 weeks or a springtooth harrow each week (Derscheid, 1979).

C. Cultural control - In areas where planting of competitive crops is possible, crops such as sudangrass or buckwheat may be utilized. Competitive cropping reduced leafy spurge stands by 50% in the first year of trials, and 80% in the second year when given 3 cultivations before seeding, and with stubble plowed after harvest (Derscheid, 1979).

Elimination of leafy spurge was also achieved in 2 years following planting of close-drilled forage sorghum or soybeans. A short season of intensive cultivation, followed by planting of fall seeded crops of bromegrass, reduced leafy spurge populations by 95% (Derscheid, 1979).

Seeding of spring-seeded grains or alfalfa is not recommended due to the superior competitive ability of leafy spurge, which emerges earlier in the season and which has allelopathic (i.e. toxic to other plants) properties.

Reinfestation of leafy spurge from seed can be prevented by using soil-building crop rotations. Legumes (such as sweetclover) will prevent establishment by most leafy spurge seedlings (Derscheid, 1979). Mechanical and cultural controls may not be suitable for use in natural areas, and such controls must be continuous to prevent regeneration from roots (R. Lorenz, personal communication).

Consult with your regional IPM coordinator before employing such methods.

4. Management Alternatives-Chemical:

Herbicides, timed for optimum control based on plant development, give excellent control of leafy spurge. Picloram (Tordon®) and 2,4-D are considered to be among the most effective herbicides for leafy spurge control. Control is most effective when applied during flower and seed development or during fall regrowth before the first killing frost. Picloram is considered to be the most effective herbicide when applied with a roller applicator. The best times for application are considered to be from mid-June until just before seed dispersal in July. The early part of this period is best to control established plants and to prevent seed development. Applications of herbicides later than July do not prevent seed dispersal. Viable seeds remain in the soil for several years following picloram treatments (Bowes and Thomas, 1978). Control effectiveness declines with low soil moisture and unseasonably high or low temperatures. Roots on established plants are killed to a depth of about 18 inches, and reapplications must be made every 3 years (Lacey et al., 1984). Picloram may be used on young plants to achieve complete eradication (due to less extensive root systems). Picloram treatments are not recommended for control of leafy spurge among trees due to the long residual effects in soil of this herbicide, which is toxic to trees (Lym and Messersmith, 1983). Yearly applications of 2,4-D will control leafy topgrowth of leafy spurge growing among trees.

Glyphosate is effective after the seeds have filled their pods in mid-summer or during fall regrowth. Glyphosate gives less long-term control when used on spring growth. Glyphosate treatments should be followed by treatments of picloram or picloram - 2,4-D mixtures the following spring. Glyphosate applied during the fall period of regrowth until the first frost, and followed by spring applications of 2,4-D, is also recommended for spurge control

among trees. Care should be taken not to expose tree foliage to glyphosate.

Small infestations should be controlled at once with picloram or Banvel® (to avoid spreading).

These herbicides give 90%-99% control in the first year. Treatments should be followed up for several years because topgrowth only is killed and roots will continue to regenerate. See Alley (1979) and Lym and Messersmith (1983) for further details.

Applications of herbicides must be made on a yearly basis due to the rapid regenerative ability of spurge and the poor translocation of herbicides within the plant (R. Lorenz, personal communication).

Use of plant growth regulators, alone or in combination with herbicides, does not significantly reduce leafy spurge shoot growth or root growth when compared to the effects of herbicides used alone (Ferrell and Alley, 1984a).

Consult your regional IPM coordinator to determine which, if any, herbicide is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Monitor leafy spurge by ground checks or aerial surveys using false color infrared film.
2. Determine injury levels based on land usage (local weed ordinances should be acknowleged).
3. Use cultural or mechanical controls to reduce small to medium infestations. Consider the use of controlled grazing by sheep as a biological control.
4. Use registered herbicides where appropriate; applications should be timed for best control, and follow-up treatments should be applied when necessary.

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V. PERSONAL COMMUNICATIONS

Lloyd Andres, Research Entomologist
USDA Biological Control of Weeds Research Unit
1050 San Pablo Ave.,
Albany, California
94706

Susan Batra, Research Entomologist
Beneficial Insect Introduction Laboratory
USDA Agricultural Research Center
Beltsville, Maryland
20705

Ardell Bjugsted, Principle Range Scientist
Rocky Mountain Forest and Range Experimental Station
USDA - Forest Service
Rapid City, South Dakota
57709

Russell Lorenz, Research Agronomist
USDA-ARS Northern Great Plains Research Laboratory
P.O. Box 459
Mandan, North Dakota
58554

NATIONAL PARK SERVICE
IPM Information Package

MOSQUITOES

Final Report

27 July 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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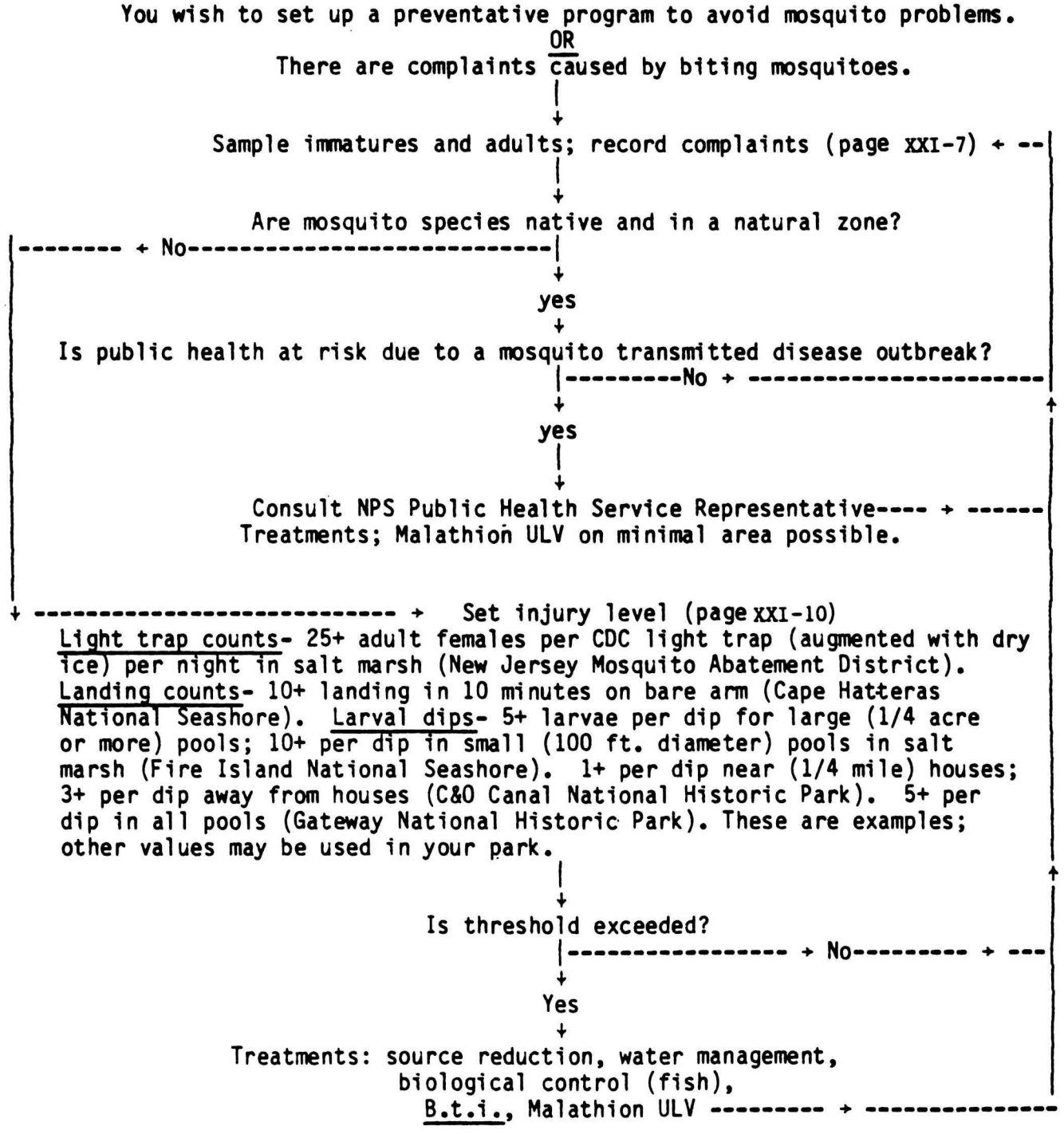
I. MOSQUITO IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. MOSQUITO BIOLOGY AND ECOLOGY

1. Species Described:

Major pest genera (other genera may be of local importance):

A. Aedes

B. Anopheles

C. Culex

See pages 134-166 of U.S. Department of Health, Education, and Welfare (1967) for a comparative key to common mosquitoes. Also see Darsie & Ward, (1981) for detailed keys to larvae and adult females of all species found in North America.

2. Geographic Distribution:

Mosquitoes are found throughout the world on every continent except Antarctica. They occur wherever liquid water exists for breeding.

See Hackett & Giraldi (1982), Carpenter (1955), Pratt (1959), or Green (1982), for detailed information.

3. Habitat:

A. Aedes - Species in this genus generally breed in temporary or isolated pools of water such as woodland pools, flood pools, pools in salt marshes, rock pools, tree holes, etc.

B. Anopheles - Species in this genus generally breed in permanent water such as ponds, wells, seeps.

C. Culex - In general, species in this genus breed in permanent water. Culex mosquitoes often breed in polluted water and are fairly common around towns and in homes.

4. Hosts:

Female mosquitoes bite to obtain blood for egg development. Different species attack different hosts (e.g., humans or other mammals, birds, reptiles, amphibians). Some species only attack one host group while others are more general feeders. Females find hosts primarily by detecting the carbon dioxide (CO_2) exhaled by the host.

5. Life Cycle:

A. Aedes - Aedes mosquitoes usually overwinter in the egg stage some species overwinter as larvae, pupae, or as hibernating adults). Eggs may hatch (depending on the species) as soon as ice melts in woodland pools (Ae. canadensis) to throughout the season. Most Aedes mosquitoes produce one generation per year. Some species may have several generations depending upon water temperature, and the number of floodings or amount of rainfall. Again, depending on the species and water temperature, growth from egg to adult takes from 4 days to a month. Aedes species normally oviposit above the water line. Eggs hatch when flooded. Some species (floodwater and saltmarsh mosquitoes) lay eggs up to several feet above the mean water level; spring floods or high tides inundate the eggs, causing them to hatch.

Larvae (wrigglers) are found only in water. They breathe air at the surface. Larvae pass through 4 stages or instars before they pupate. Larvae feed on microorganisms by means of fan-like hairs which sweep water to the mouthparts.

Pupae (tumblers) are found only in water. Like larvae, they breathe at the surface, but pupae do not feed. The pupal stage is essentially a time when the mosquito rebuilds itself to form a winged, non-aquatic, sexually mature adult stage from the larval tissues.

Adults are the flying reproductive stage. Females are biters; they can fly from 1 to 25 miles for a blood meal, depending on the species (blood is used for egg development). They also drink nectar from flowers for flight fuel. Males do not bite; they sip nectar from flowers. Males emerge as adults before females (this may be useful in monitoring programs). Some species can produce eggs without a blood meal.

B. Anopheles - Anopheles mosquitoes have life cycles similar to those of Aedes species with several important exceptions:

Anopheles mosquitoes ususually overwinter as hibernating adults (some species overwinter as larvae or in the egg stage).

Most Anopheles mosquitoes lay single eggs on the surface of calm water in wind sheltered locations. Choppy water or running waters are

not suitable for mosquitoes because waves may strike ovipositing females causing them to be trapped by surface tension, or turbulence may drown larvae. These areas also generally contain fish which feed on mosquito larvae.

C. Culex - Culex mosquitoes have life cycles similar to those of Anopheles species. They differ in that most species of Culex lay their eggs in multiple "rafts" which float on the surface of the water.

6. Seasonal Abundance: Mosquitoes may breed and develop any time from the beginning of spring to the first hard frost of fall. In general, populations are highest in summer and early fall. Under ideal conditions, many species can complete development in less than a week resulting in large populations of flying adults.

7. Effects of Environmental Factors: Mosquito populations are influenced by temperature and rainfall. Prolonged or abundant rains can cause more eggs to hatch by raising water levels; large numbers of adults can breed in the larger, more permanent pools. Temperature has less effect on large pools due to the thermal buffering capacity of water. Conversely, lack of water and low temperatures result in lower populations.

8. Medical Importance:

8.1. Direct Effects: Although mosquitoes have been reported to cause death from excessive blood loss in livestock (presumably a helpless human could suffer a similar fate), the direct effect of mosquitoes and mosquito bites is usually annoyance.

8.2 Indirect Effects: With the decline in frequency of malaria and yellow fever, encephalitis has become the most important mosquito-vectored disease in the U.S. Encephalitis is a viral disease which attacks the central nervous system. Five types of arboviral (arthropod-borne viral) encephalitis occur in the U.S. They are eastern equine encephalitis (EEE), western equine encephalitis (WEE), California encephalitis (CE), St. Louis encephalitis (SLE), and Venezuelan equine encephalitis (VEE). Each type is caused by

a different virus or virus complex, and each has a different disease cycle. CE and VEE are transfered by mosquitoes among small mammals and then to man or horses (in VEE) often by the same mosquito species. EEE, WEE, and SLE are transmitted from bird to bird by one mosquito species and from bird to man or horse by another mosquito species.

Dog heartworm is a mosquito transmitted nematode parasite of dogs and occasionally of man. It occurs throughout the U.S. and is common in the East. Untreated, it can be fatal to dogs. The precise vectors of dog heartworm in the U.S. are not entirely known but many species of mosquitoes have been infected under laboratory conditions. Use of medication to protect dogs from heartworm is generally a more effective means of controlling this disease than is mosquito management.

9. **Natural Enemies:**

Mosquitoes have many natural enemies, ranging from bacteria and insects to fish and birds. Natural enemies attack all stages of the life cycle from egg to adult. Many natural enemies can be and are used to provide biological control.

III. MOSQUITO MANAGEMENT

1. **Population Monitoring Techniques:** Monitoring consists of site visits to potential mosquito problem areas, and sampling and interpretation of data. Data to be sampled include: complaints of bites to determine the degree of nuisance (injury level); numbers of mosquito immatures and adults (to determine which species are present and their numbers) and people usage patterns (as related to creation of mosquito breeding sites and as related to contact between mosquitoes and people). Keeping records of observations and samples, including the use of site maps, is essential. Local mosquito abatement officers should be consulted before monitoring begins.

A. Aedes The initial site visit should be made before mosquitoes have hatched in the late winter/early spring. This will allow time to identify all potential mosquito breeding sites and biting areas, and implement changes to avoid mosquito problems (habitat modifications, purchase of control agents, etc.).

1. Monitoring larvae and pupae - Mosquito larvae and pupae are monitored by a 10-dip method using a standard dipper made of enameled metal or aluminium. See Hackett and Giraldi (1982), for details. Dippers can be purchased through biological supply houses or hardware stores. Counts are recorded and averaged for each pool.

   Take 5 samples from open water and 5 samples from the pool edge, particularly an edge with vegetation. If possible, intermingle samples from sunny and shady areas as well. Try to be consistent in sampling technique. See Hackett and Giraldi (1982) for further details.

   Since larvae and pupae will dive to the bottom of the pool if disturbed, the recommended method of sampling is as follows: (a) to sample in open water, gently cut the surface of the water with the dipper edge and allow immatures to be drawn in; (b) to sample along banks or in dense vegetation, press the dipper into the side of the bank or against dense vegetation, and (as above) draw immatures into the dipper. Try not to cast a shadow on the area you are sampling. If larvae become disturbed, either wait until they reappear, or sample different areas within the same pool. Mosquito larvae not accesible with a dipper (i.e., in tree holes, tires, etc.) should be sampled

with a large basting syringe and emptied into a white pan for counting. (Basting syringes can be obtained in housewares stores; white pans or developing trays are available in photography shops).

Sample all selected indicator pools (representative of all pools in the park area where you are considering control). Establish a sampling circuit and sample all selected pools on a regular basis, usually weekly (spring and fall) or daily to weekly basis (summer). If no permanent habitat changes are made, sampling should continue until the first hard frost of autumn.

To make sure that the immatures you are controlling are the same mosquitoes that are the problem, comparisons of larval and adult specimens sampled are necessary. Use available literature and CDC Keys to identify specimens. Unless you can identify both adult and immature specimens to the species level, it is better (at least in the beginning) to send specimens out for identification. Contact local universities, colleges, or other institutions for such services.

2. Monitoring adults - To monitor adults, sample all nuisance or disease transmitting species in your area (see your local mosquito abatement district officer for a list). Establish a sampling circuit and sample on a regular daily or weekly basis. Begin sampling as soon as larvae pupate and continue until the first hard frost of autumn. Landing counts (See 2.b.) are extremely useful during the day. However light trap counts must be made at night. Sample all areas where mosquitoes may be a nuisance due to their biting, particularly park areas adjacent to residential areas. Check with the local mosquito abatement officer for proper placement of traps.

a. Light traps

Light traps catch large numbers of mosquitoes, and are simple and inexpensive over the long run. They are <u>not</u> a control measure, but are a monitoring tool only. Different traps catch different mosquito species; therefore, it is important to use a trap that will survey all problem mosquitoes in the area. Consult your local mosquito abatement district officer.

New Jersey or CDC Mini traps are the most commonly used. Since mosquitoes are primarily attracted to carbon dioxide in the host's breath, light traps

are often augmented with dry ice. A 1 lb. (or larger) block of dry ice is wrapped in newspaper or foil, and hung next to the trap. CO_2 supplements increase the mean catch up to 100 times of that in light traps without CO_2. It also allows traps to be used on moonlit nights or around street lights which normally "compete" with the light from most traps. Use of dry ice allows traps to be used in daylight to sample day flying species as well as species not attracted to light (such as many Anopheles).

Downing (1979) provides detailed instructions for interpreting mosquito trap data. If the use of this procedure is not possible, determine average catch from all traps set in an area. Consider using the services of local mosquito abatement district offices in analyzing the data.

b. Landing counts

Landing counts on humans are useful in that they provide an accurate monitoring method of the species that are biting human beings. In order for this index to be useful, counts must be made during mosquito feeding periods. Since many mosquitoes feed during the day, landing counts are often a valuable monitoring tool to use during daylight hours. They can also be used at night from 30 minutes before sunset to 30-45 minutes after sunset to sample crepuscular biters (those active before and after dawn or dusk).

The person conducting the landing count survey walks into the survey area to disturb the mosquitoes. After waiting about a minute, he counts(and if possible, collects with an aspirator) the mosquitoes landing on arms or legs. Counts on clothing below the waist result in better data with less discomfort. Depending on mosquito abundance, time intervals of 1, 5, or 10 minutes may be used.

Regardless of the method or time interval used, the same procedure should always be followed so that comparisons between counts can be made. The same person should always be the "bait" because mosquitoes are attracted differently to different people.

As with other monitoring measures, little data exist on the relationship between landing counts and injury levels. This might be determined by correlating landing counts with citizen complaints. This technique is especially useful early in a monitoring program, before long-term trapping

data are collected. The landing count survey samples that portion of the female mosquito population which is seeking human blood.

c. Evaluation of treatment success-

The easiest way to evaluate treatments is to compare indicators of mosquito nuisance before and after treatment. Since the ultimate goal is to reduce mosquito biting to a tolerable level, changes in indicators which measure this (complaints or annoyance determined by surveys) are the best criteria for evaluation of the entire program. In many cases, the effectiveness of specific treatments can be evaluated by monitoring changes in the sizes of populations of immatures or adults.

A simple evaluation method (one which does not require complicated statistical analyses) is to plot complaints, versus counts of immatures or adults on graph paper. Complaints should correlate with counts of mosquito adults in light traps and immatures in pools.

B. Anopheles - See Section III.1.A. (Aedes).

C. Culex - See Section III.1.A. (Aedes).

2. Threshold/ Action Population Level:

Injury levels will vary from park to park. They should correlate with complaints, adult trap monitoring, and larval monitoring. Record the number and location of complaints, decide what you consider to be an unacceptible number of complaints: this is the injury level. Establish an action threshold. Determine how many mosquitoes are flying as indexed by trap counts and landing counts to cause the number of complaints to reach the injury level. Determine how many mosquitoes will emerge if larvae are untreated. The action threshold is the number of flying adults and untreated larvae which will, after emerging, push the average trap catch to one mosquito per trap per night below the injury level.

Working injury levels/action thresholds have been set in several units of NPS. Larval samples of .1 to 5 per dip, adult trap counts of 25+ adult females per night, and landing rates of 10+ in 10 minutes have been used in IPM programs with success.

3. Management Alternatives - Nonchemical:

A. Aedes

1. Water management - Since all mosquitoes are aquatic in the immature stages, good water management is the preferred treatment. In comparison to adults, larvae are more concentrated and easier to deal with. Any

mosquito abatement program should have larval control, particularly water management, as its first priority.

Water management may provide control for as long as 10 years without maintenance costs and may pay for itself (in terms of money saved in yearly pest control) in some situations within 4 years (Shisler, 1981). Caution should be taken in natural areas so that natural drainage patterns are not changed.

Water management may be as simple as removing breeding sites such as discarded cans or old tires in which several species (e.g., Aedes aegypti; the yellow fever mosquito) breed.

Drainage - Many ground pools and other breeding sources may be eliminated by connecting them via graded ditches to larger and deeper bodies of water such as rivers or lakes. Ditching serves two purposes: in some cases the water drains out of the potential breeding sites, in others, fish gain access to isolated pools and prey upon the larvae there (this is usually the case in salt marshes). Ditches can be constructed using hand tools or machinery especially designed for this purpose.

Filling - Many ground pools that are not easily drained may be eliminated by filling them with earth, using hand tools or machinery.

Ponding - Ponding essentially means turning a temporary pool into a permanent one. In some cases, the water level may be raised to the point where it can support mosquito-eating fish which are then stocked. Variations on ponding include the construction of sumpage wells, where the water is drained into a relatively deep pool and stocked with predators or other natural enemies. In salt marshes, pools may be dug to serve as refuges for fish during low tides. When high tides flood the marsh, fish are then able to forage widely. Water impoundment (stop ditching) in salt marshes is another variation of ponding. This technique is used in areas in which large numbers of breeding pools occur over an extensive area. A large body of standing water 6-12 inches in depth is created in these areas by use of low level dikes. For example, impoundments have been built to interrupt tidal flows and allow water from upland areas to flood salt marshes. These impoundments, although controlling salt marsh mosquitoes, may create breeding area for other pest species. The area of impounded water should, therefore be monitored if this technique is used.

In some areas this method has resulted in geobiochemical problems (e.g. increased vegetative succession, decreased diversity, and increased number of other species of mosquitoes).

2. Biological control -

a. Fish - Mosquito eating fish have long been used for mosquito control in many areas of the world. The most commonly used species is the mosquito fish, Gambusia affinis, but many other fish species have been used with varying degrees of success. Fish are particularly useful mosquito control agents in the following habitats:

Deep permanent pools - Due to their temperature buffering capacity, these provide the best conditions for fish survival. Permanent pools support algae, which are desirable food for young fish and may serve to prevent cannibalism by adult fish. Before using fish in permanent pools, check to see if fish are already present and are controlling mosquitoes. Determine the thickness of ice in winter. If ice becomes too thick, fish must be restocked in spring.

Large areas of temporary water - Use of fish in temporary pools may be useful where fish are easily obtained and where use of water management or other methods would be prohibitively expensive. This procedure was used on an experimental basis in the high salt marsh area of Fire Island National Seashore; fish in this case were collected from the lower marsh.

Highly polluted water - Fish may be useful in areas which are too polluted (high in organic material) for other methods to work. Fish have been used to control mosquitoes in primary sewage treatment ponds and tanks.

Before using fish for biological control, several factors must be considered: in ornamental ponds, goldfish will eat mosquito larvae but are not considered to be particularly useful in mosquito control. Water temperature must be above 50°F for guppies to survive.

Both mosquito fish and guppies can tolerate low dissolved oxygen levels and high levels of pollution. Mosquito fish are able to gulp surface air in low oxygen environments. Guppies can survive and reproduce in sewage treatment facilities and tolerate high metal ion concentrations. Mosquito fish have been used in sewage treatment plants but must be gradually

acclimated first. Both fish species can tolerate a wide range of pH and salinity.

Neither mosquito fish nor guppies do well if predatory fish (such as bass or sunfish) occur in the same waters unless there is very shallow water for a refuge. Guppies are outcompeted by mosquito fish and soon disappear from areas where the two occur together. Birds such as herons and kingfishers may be problems in small bodies of water with limited populations of fish.

Fish exotic to an area should not be introduced into waters where they may compete with native (endemic) species. In Texas, the Big Bend Gambusia (Gambusia gagei) was nearly eliminated when the mosquito fish (G. affinis) was introduced into its only known habitat, a pond near the Rio Grande. Other rare or endangered fish occur in scattered areas throughout the U.S., particularly in the Southwest. Consult with park and regional resource management personnel before making any introductions.

Fish effectiveness is decreased in the presence of floating vegetation which provides cover for mosquito larvae. Overhanging walnut or mulberry trees may lower effectiveness due to toxins released by leaves which fall into the water.

For more detailed information on mosquito control using fish, see Hackett and Giraldi (1982) and Coykendall (1980).

b. Predaceous insects - Insects, especially backswimmers (notonectids), may, when present in significant numbers, stabilize mosquito larvae populations. Although predaceous insects may be slow in reducing high larval numbers, when used in conjunction with other control measures (fish, B.t.i.), they can keep larval populations below the action threshold. The ratio of backswimmers to mosquito larvae per dip may provide an action threshold for determining whether additonal control measures are necessary.

c. Parasitic nematodes (roundworms) - Romanomeris culicivorax kills mosquito larvae by penetrating the body and feeding on internal tissues. The larva eventually ruptures, releasing more nematodes. Successfully tested in the field throughout the world, it is persistent in breeding pools and survives at least two years after initial introductions. It can be obtained by special order from:

The Nematode Farm
2617 San Pablo Ave.
Berkely, CA 94702
ATTN: Andy Wilson
(415)527-8260

B R Supply Company
P.O. Box 845
Exeter, CA 93221
(209) 732-2738

d. Bacteria- The bacterium Bacillus sphaericus has been used experimentally to suppress larval populations. Similar to B.t.i., it can be used in polluted water where B.t.i. is less effective.

Bacillus thuringiensis israelensis (B.t.i.) is quickly becoming one of the most important mosquito control tools worldwide. It is highly selective for mosquito and black fly larvae. It is nonhazardous to human beings, other mammals, birds and predaceous insects, is reasonably priced and easy to ship and store, easy to apply, and fast acting.

e. Fungi- The parasitic fungus Lagenideum giganteum acts in much the same way as do nematodes, infecting the mosquito larva's body and growing on tissues, eventually reproducing and infecting other larvae. Recently mass produced, it should be available commercially soon. For further information, contact: J. Kerwon or R. Washino, Department of Entomology, University of California, Davis, Cal. Other fungi are under study; as yet, none are registered for use against mosquitoes.

3. Screens and repellents may reduce mosquito annoyance. Screens over windows and doors will keep many mosquitoes from entering structures. An 18x18 mesh size works best. Protective clothing includes long trousers, long sleeved shirts, gloves, and in some areas, hats and veils. Many repellents, varying in effectiveness and duration are currently commercially available.

B. Anopheles - See III.3.A (Aedes).

C. Culex - See III.3.A. (Aedes).

4. Management Alternatives - Chemical:

Although water management is the preferred way to control mosquitoes, chemical controls may sometimes be necessary. Consult your regional IPM Coordinator to determine which pesticide, if any, is best suited to your mosquito management program.

A. Aedes

1. Larvicides - In situations where B.t.i. is not useful (in highly polluted or alkaline water), the following chemicals are registered for larval control: chlorpyrifos, fenthion, pyrethrin, and temephos. Check the labels for rates and formulations. Fish are highly sensitive to most larvicides. Oils are often used in control of immatures. They act by clogging the breathing tubes of larvae and pupae causing suffocation. Oils commonly used are kerosene, diesel #2, fuel oil #2, ARCO larvicide, and Flit MLO®. All but the last may be toxic to fish.

   Insect growth regulators (IGRs) such as methoprene do not kill larvae, but prevent them from developing into adults. Timed-release briquets are available and have been used in a variety of situations. Some IGRs (such as Dimilin which inhibits chitin formation) may have adverse effects on nontarget species, but most are considered harmless to most non target species. They are normally used in small volumes of water. They have no effect on pupae or 4th instar larvae.

2. Adulticides - When adulticides are needed, it usually means something has gone wrong with the IPM program. An IPM program directed at immatures normally obviates the need for adulticide use. However, in certain circumstances, adulticide use may be necessary.

   Most adulticide applications are ultra-low volume (ULV) applications, in which undiluted pesticide is broken into microscopic droplets. A small amount of pesticide is used (2-4 oz/acre). Malathion, pyrethrins, resmethrin, naled, chlorpyrifos, and fenthion are used in ULV applications. ULV applications are quickly dispersed and temporary, killing only insects which are contacted by droplets. Mist blowers may be used to spray dilute pesticides onto surrounding areas to kill resting mosquitoes. Malathion, naled, pyrethrins, and resmethrin can be used in this method. Fogging is rarely used due to expense, lack of coverage, lack of persistence, and its negative effect on air quality.

B. Anopheles - See III.4.A. (Aedes).

C. Culex - See III.4.A. (Aedes).

5. Summary of Management Recommendations:

1. If possible, begin water management program to reduce suitable breeding habitat.

2. Use biological control agents such as fish, nematodes, or predaceous insects to reduce larval populations. Use B.t.i. instead of chemical larvacides.

3. If use of B.t.i. is not possible, treat larval populations with approved pesticide.

4. Treat adults if necessary with approved pesticide such as malathion ULV.

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V. Sample Mosquito Monitoring Form

Site Monitoring Form

Map

N
W-|-E
S

Date: Reference #: Samplers:
Location, Distance, and Name of Nearest Town (or major landmark):

Land Use:

Adults	Immatures
Landing counts time of count: number & species: Trap catches: type of trap: time of trapping: # and species: Collections: Y N Photos: Y N Treatment: Material: Rate: Area Treated: Equipment:	Pool type: Pool bottom: Pool depth (in.): Water conditions: stagnant, moderate, fast clear, turbid, polluted Mosquito collections: Y N Species present: Photos: Y N Predators: Treatment: Material: Rate: Area Treated: Equipment:

Other Recommendations/Comments

Instructions for use - Notes on filling out the site visit form

- Always assume someone else will be the next to visit the site; be as clear as possible. Use pencil-ink will run if wet.

- Habitat information (pool type, pool bottom,etc.) can be used in predicting where and when to expect mosquitoes to be a problem in the park. This is because mosquitoes are not found in every pool of water. Correlations between mosquito presence and habitat type might allow you to anticipate problems.

- Pool type: pond, lake edge, woodland pool, swamp, marshy depression, stream margin, rock pool, seepage spring, flood pool, ditch, pit, well, artificial container (specify), tree hole, wheel rut, other (identify).

- Pool bottom: mud, sand, gravel, rock, leaves

- Pool depth: in inches

- Water conditions: circle one in each group

- Sketch a map of the area on the upper half of the form. Draw outlines of all pools. Include landmarks, direction of nearest town, etc.

- Take a 10 dip sample and record data beside sample pool on map. Use an "S" to mark the area of the pool sampled.

- For adult sampling, specify the type of adult monitoring used (ie. CDC light trap, landing counts, etc.) The map is large scale, when adult monitoring is done in areas removed from the breeding pools. This provides a better picture of the area being monitored and the relationship to human activity.

NATIONAL PARK SERVICE
IPM Information Package

HOUSE MOUSE

Final Report

February 1984

Submitted To:

Dr. Michael Ruggiero
Biological Resosources Division
National Park Service
Washington, D.C.

Submitted By:

John Muir Institute
743 Wilson Street
Napa, California 20852

NATIONAL PARK SERVICE IPM INFORMATION PACKAGE

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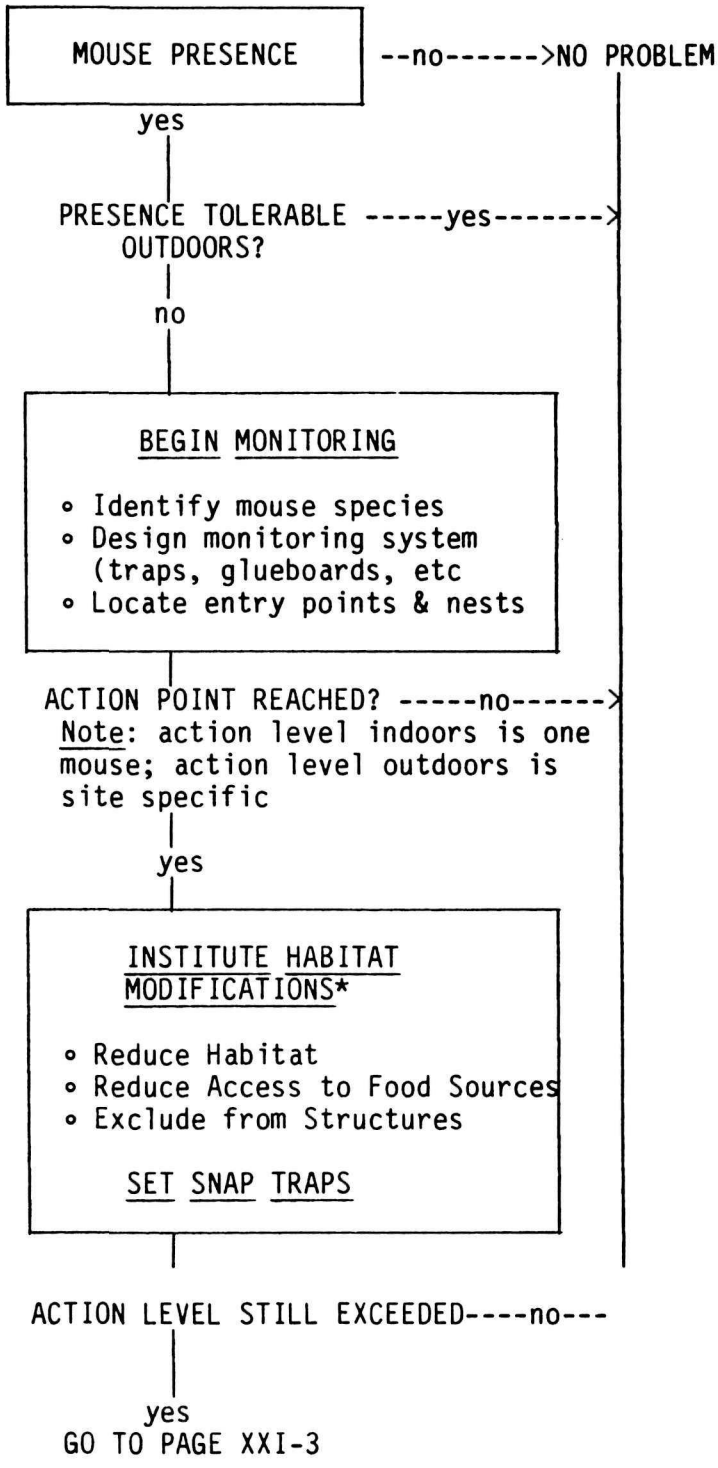
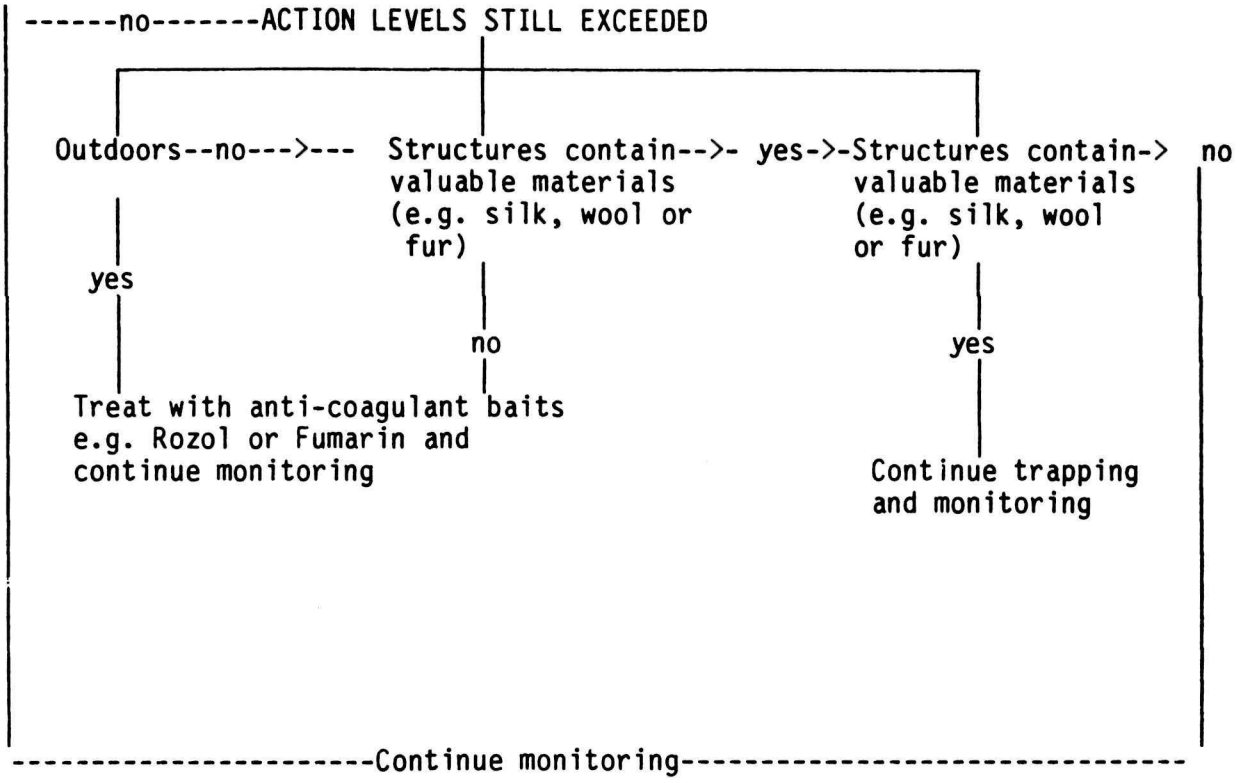
I HOUSE MOUSE IPM DECISION TREE



I HOUSE MOUSE IPM DECISION TREE CONTINUED



* Outdoor habitat modifications can include reducing vegetation and physical objects which provide hiding places and protected runways close to structures. Indoors, destroy nests and exclude mice from stored foods, wastes and nest-making materials by placing these in closed metal or glass containers.

II BIOLOGY AND ECOLOGY OF HOUSE MOUSE

1. Species Described:

The first step in assessing the pest problem is to identify correctly the invading species. Table 1 lists the characteristics of native mice species which could be confused with the house mouse, Mus musculus L., and the young roof or sewer rat, both of which were accidentally imported into North America from the Old World. Table 2 compares the house mouse with the Norway rat and the roof rat. A field key for common rodents, including M. musculus, is presented by Pratt and Brown (1976). Also, see the Pictorial Keys issued by the Center for Disease Control (CDC 1967).

2. Life History:

The reproductive rate of house mice is formidable. Mice become sexually mature when 2-3 months old. The females are polyestrus, having periods every 4 days. Mating takes place over the entire estrus period and at other times as well. A post-partum estrus with delayed implantation during lactation also can occur. Assuming an average litter size of 6.7, and a gestation period of 20 days plus an eight day period during lactation when estrus does not occur, one pair of mice theoretically can produce 87 young per year (see Table 3).

Some captive females have produced 100 young per year (Storer 1960). In urban mouse populations the average proportion of fecund females found pregnant during the year was 22% (Laurie 1946). Given such a potentially high reproductive rate one can see that for most indoor mouse populations various environmental factors must limit actual population increases. A female stops producing young about 15 months of age, but may live much longer. Males may live up to 3 years (Ebeling 1975).

An indoor population is limited by available food, shelter and competing species. Since rats are predaceous on mice as well as competitors for food and shelter, their removal often allows mouse populations to increase (Shenker 1973) because food and habitat previously taken by rats is now available. Thus, the previous presence of rats in a structure may be a prediction of a later infestation with mice.

TABLE 1.

COMPARING MUS MUSCULUS WITH OTHER RODENTS

MISTAKEN FOR HOUSE MOUSE

OTHER RODENTS	HOUSE MOUSE
Young roof or sewer rat, Rattus spp.: head and feet large for its body; tail naked and longer or shorter but not equal to head and body combined.	Feet and head proportional to its body; tail is semi-naked and is as long as the body and head combined.
Deer mouse or white-footed mouse, Peromyscus spp.: white venter (underside), bicolored tail.	Venter (undersides) brown or gray; lacks distinct bicolored tail.
Meadow mouse or vole, Microtus spp.: body plump, short hairy tail, eyes and ears small in proportion to head.	Body more slender and smaller than vole, long tail, eyes and ears large in proportion to head.
Harvest mouse, Reithrodontomys spp.: grooved upper incisors.	Flat, notched (not grooved) upper incisor.

TABLE 2.

DISTINGUISHING COMMON RODENTS*

CHARACTERISTIC	NORWAY RAT	ROOF RAT	HOUSE MOUSE
Scientific Name	Rattus norvegicus	Rattus rattus	Mus musculus
Other Common Names	Brown, Wharf or Sewer Rat	Black, Ship, House Rat	--
Adult Weight	11 oz	7 oz	½ oz
Snout	blunt	pointed	pointed
Ears	small,short hairs	large, naked	large
Tail	dark above pale beneath	all dark	small all dark
Fur	brown with black, shaggy	gray to black, smoother	light brown to gray
Droppings	capsule-shaped	spindle-shaped	rod-shaped
Food Needs	1 oz/day	1 oz/day	1/10 oz/day
Water	free water	free water	from food
Climbing	can climb	active climber	good climber
Nests	mainly burrows	walls, attics, trees	near or within stored materials
Swimming	excellent	can swim	can swim
Litter size	8-12	6-8	6-7
Litters/year	7	6	8, up to 10

* Adapted from: Pratt et al. (1977); Pratt and Brown (1976); Howard and Marsh, (1974); Marsh and Howard (1977).

TABLE 3.

BASIC INFORMATION ON HOUSE MOUSE BIOLOGY*

CHARACTERISTIC	DESCRIPTION
Sexual cycle	polyestrus, every 4 days, all year
Size of litter	6.7, based on 9 field studies
Litters/year	up to 10, based on food available
Age at weaning	21 days
Gestation period	19-21 days
Age at mating	6-10 weeks
Life span	1-2 years, maximum 6 years

* From Berry (1970); Marsh and Howard (1977).

Once other species are excluded from consideration, the major factors limiting the size of mouse populations are food and shelter. Water is seldom if ever limiting since this species can fill its water needs from the food it eats, even dry cereals. This capability and its small size make M. musculus particularly well adapted for arid building interiors. In response to stress (e.g. excessive heat) it can induce a torpor or dormancy which conserves its physiological reserves, (Fertig and Edmonds 1969).

3. Impact of House Mouse:

Mice damage food, clothing, documents and other human artifacts and structures by gnawing, urination and defecation. The damage to food stores from mice wastes is probably 10 times the damage attributed to direct feeding. Many fires of "unknown cause" may be due to mice (and rats) which chew through wires.

Although rigorous proof of the role and extent of involvement is unavailable mice have been implicated in a number of important human diseases (see Rowe 1966, and Table 4). Webber (1982) summarizes the information about the human pathogens transmitted by mice and rats, but unfortunately does not distinguish in all cases which species of rodent is implicated with which pathogen. Conclusive evidence linking mice to transmission of LCM virus has been documented (Webber 1982). This arenavirus virus causes Lymphocytic chorimeningitis, (LCM). LCM is one of the causal agents of acute aseptic meningitis which is known to have caused human deaths, although infections are usually mild. The route of transmission is probably respiratory through dust contaminated with mouse urine, contaminated food and drink, or by direct contact.

Surveys of mouse populations indicate that up to 69% are infected (probably chronic carriers) of LCM virus. The house mouse continues to be the major reservoir of this virus (Evans 1976; Webber 1982). This association alone justifies mouse control from a public health point of view, but the association with many other human pathogens indicates a potential hazard exists wherever mice come into contact with human populations, their pets or laboratory animals.

4. Natural Enemies:

Outdoors M. musculus is preyed upon by owls, hawks, snakes, cats, coyotes and many other predators. Weber (1982) documents the many human pathogens which mice (and rats) transmit to humans, many of which also decimate mouse populations. The common house cat, Felis cattus, is a major house mouse predator in domestic and feral situations.

TABLE 4.

SOME MOUSE-IMPLICATED DISEASES OF HUMANS*

DISEASE	CAUSAL AGENT	TRANSMISSION
Bubonic plague	*Yersinia pestis*	infested flea, e.g. *Xenopsyllus cheopis*
Salmonellosis	*Salmonellia* spp.	contaminated food
Rickettsial pox	*Rickettsia akari*	by house mouse mite, *Liponyssoides sanguineus*
Lymphocytic choriomeningitis	LCM virus	contaminated food, dust on fecal particles
Ratbite fever	*Spirillum minus*	by bite
Tapeworms	*Hymenolepis nana* *H. diminuta*	droppings contaminated food
Favus, ringworm	*Trichophyton schoenleinii*	direct contact or from mites
Dermatitis	house mouse mite, *L. sanguineus*	bites humans
Leptospirosis, or infectious jaundice	*Leptospira ictero-haemorrhagiae*	contaminated food, water, etc.

* See Webber 1982, for a more comprehensive treatment of these and other mouse implicated diseases.

III HOUSE MOUSE MANAGEMENT

1. Population Monitoring Techniques:

Monitoring programs consist of an initial inspection followed by regular observations and record keeping. The objective of monitoring is to; discover damage or markings that indicate mouse presence, locate the mice, assess population density, detect modes of entry, harborage and sources of food, and to time and evaluate effectiveness of treatment activities.

In areas where food and grains are stored or where mice have been a problem in the past, preventative inspections should occur before actual mouse presence is observed in order to detect new infestations when population levels are low. The first sign of infestation is usually the sight of a mouse running across an open space. Other indications include droppings, nest material, gnawing damage, tracks or smudge marks. Signs of larger, more long-term infestations include frequent sightings of mice and the presence of urinating pillars, composed of collections of grease, urine and dirt.

If large infestations are suspected, particularly in large buildings such as warehouses, the most effective time to make initial inspections is at night when most mice are active. Use of a strong flashlight will aid in making visual estimates of populations. A characteristic musky odor of mice will help differentiate them from rats. Wet and dry stains of mice and rats fluoresce under a black light (as do other substances such as glue), and this technique may be helpful in determining presence and locations of mice.

It is difficult to make population assessments for the house mouse which probably accounts for the paucity of useful documented studies. The best and most accurate censusing technique is snap trapping (see Section III.3)

Records should be kept of trap catches to assist in evaluating relative population density as well as effectiveness of suppression treatments. Population density variations over time and among structures can be compared by calculating an index of the number of trapped mice per number of traps set per night e.g., 40 mice/100 traps/night = 40% (Marsh and Howard 1977).

Other methods for determining mouse presence and relative population densities include use of talc and direct feeding. Patches of talc can be spread out at various intervals throughout a building and monitored. The percentage of talc-covered areas containing mouse tracks can

confirm mouse presence and indicate relative population size. These talc patches can be used both before and after a control operation to evaluate effectiveness.

Direct feeding can be used to assess populations also. This requires placing measured amounts of finely ground cereal in numerous locations throughout a building. Whole grains or chunk baits will be carried off and thus are not suitable.

Live trapping, or mark and release techniques generally are useful only for special research purposes. They are not recommended for an IPM program largely because of the extra time involved.

The frequency of monitoring by traps should be dependent on a number of variables including sightings of mice, mouse droppings or damage presumed to be mouse-caused, previous occurrence of mice in the area, known attractiveness of stored material to mice, time of year, etc. In areas where mouse presence is anticipated on a seasonal basis (e.g. in colder climates where mice migrate indoors during winter) monthly monitoring utilized during spring and summer should be increased to weekly during late fall. In areas where mice are a chronic problem, monitoring should probably occur weekly.

Inside structures, or in the area immediately ajacent to building foundations, the only important natural enemy of house mice besides humans is the domestic cat (see Section III.3). Observations of cat behavior can be useful when monitoring for mice since by their stalking and similar actions cats can indicate where new mouse invaders may be hidden.

2. Threshold Action Population Level

Injury level refers to the point in the growth of the pest population when the numbers of pest organisms are sufficient to cause some unacceptable kind or degree of structural, economic, aesthetic or medical damage (injury).

Because of their potential to damage cloth, paper and other furnishings, to contaminate food stuffs and to cause fires by chewing on electric wires, the injury level for house mice inside a building is one mouse. The exception to this may be in structures without electricity or structures that do not contain materials that may be damaged or contaminated by mice. In such cases consideration should be given to the fact that providing this mouse harborage creates a potential hazard to nearby buildings.

The suspicion of mouse presence based on observation or reasoning should be sufficient to initiate periodic monitoring with traps. The confirmation of mouse presence, based on trap catches, mouse droppings or damage to stored materials, should be sufficient to initiate control methods, emphasizing habitat modification and physical controls.

3. Management Alternatives Non-Chemical: Indirect suppression strategies and tactics are those that change the conditions that create or define the pest problem. Examples are:

a) design or redesign of the landscape, structure or maintenance for the purpose of reducing or eliminating the pest problem;

b) modifying the habitat in some major way to discourage the pest species;

c) human behavior changes including the alteration of use patterns or maintenance practices contributing to the pest problem, or education to increase tolerance levels for the "pest" species or the aesthetic damage it causes.

Preventive maintenance is the best and least expensive procedure, but is seldom used. Once a pest problem is present the life-supporting systems (particularly food and habitat) for the mice should be reduced in conjunction with removal of the mice themselves. If treatment actions are confined to mouse removal the habitat is left "open" for new invaders. Habitat modification alone still leaves existing mice free to produce damage. Thus, several suppression strategies must be combined.

Mouse proofing should be part of the original design of structures that will hold grain, seed or other human and animal foods. Where this has not been done modifications will have to be made later as a special effort. Perpendicular barriers of galvanized metal, 18-24" high, successfully excluded mice from grain piles during the great Australian mouse plagues (Winterbottom 1922).

The small size of mice makes mouse-proofing difficult. A fully-grown adult can squeeze through openings the size of a dime. Consequently, even small holes need to be searched out, stuffed with steel wool, covered with sheet metal, and/or filled with caulk, plaster or similar materials. Storage of foods, particularly grains, in tight-fitting metal or glass containers will reduce mouse access to these materials.

Spilled grains, seed or similar foods particularly attractive to mice should be thoroughly cleaned up and disposed of in mouse-tight garbage containers, or composted in hot, aerobic compost piles. Repairs to door sills and kick-plates, screens and other areas receiving continual wear should be made part of regular maintenance routines.

Information on the potential hazards from house mouse presence should be made available to both staff and visitors to counteract a frequent sentiment that domestic mice are cute and not worth controlling. This education could be particularly important where visitors occupy cabins under park jurisdiction and may feed mice for amusement.

Of the procedures available for suppression, trapping is the preferred method. Traps provide physical evidence of capture while baiting provides no such evidence and produces unpleasant odors from decaying carcasses. These carcasses may be attractive to dermestid beetles which destroy proteinaceous materials (e.g. wool, silk, fur). Simple snap traps which are widely available are effective, particularly if they have expanded triggers so they will snap when a mouse runs over them without attempting to reach for food.

Metal snap traps are available that have an opening or setting mechanism similar to that of a clothes-pin. Metal traps are long-lasting, particularly if lubricated and protected from rusting. These traps can be set quickly so many can be used at one time. The sensitivity of the trigger on the clothes-pin type traps also can be adjusted rapidly and easily. This is important since trapping mice requires the setting of large numbers of traps. The wire-spring type traps require moreltime and skill to set.

Table 5 lists common baits that have been shown to be effective for trapping house mice. Instead of food, a small piece of cotton may be attached to the trigger where the mice pull at it for use as nesting material. Cotton does not spoil as do other "food" baits. Trap shyness can be minimized by alternating different types of baits (see Table 5).

TABLE 5.

BAITS TO USE WITH SNAP TRAPS*

peanut butter mixed with rolled oats, wheat or canary seed
raisins
bread
cotton tied to the trigger

* From: Elton 1942; Schuyler and Sun 1974; Ebling 1975; Rowe et al., 1974; Frishman 1982.

Pre-baiting (where traps are left baited but not set) can be used to increase trap catches with heavily trapped or trap shy populations. Traps soiled with blood should not be cleaned since they are more effective than a clean, unused trap (Frishman 1982).

Successful trapping campaigns rely on large numbers of traps concentated in areas where mouse presence is suspected. Mice have relatively small home ranges so at least one trap every two to three linear feet is needed to insure capture. Snap traps should be placed at right angles to the runway rather than in line with it. This enables mice to be trapped when moving in either direction along the runway. Set traps out for two to three days and then move them to new locations. Continuous availability of traps over a long period of time "produces" mice that become trap-shy (Southern 1954). Also, small mice are seldom killed by snap traps and remain to re-establish the infestation at a later period. Thus monitoring at an appropriate frequency is recommended.

Traps should be handled infrequently and with gloved hands as mice can detect human odors left on the traps. New traps should be seasoned by burying in soil and grass to remove human odors. Metal traps used outdoors will last longer if coated with wax. They also require oil to keep the moving parts in working condition. Frishman (1982), recommends against the use of petroleum oils because they are repellent to mice. Lubrication with lard, other animal fat or bacon rinds will help prevent

rusting and will help attract mice. Fitzwater (1970) also reviews the history of trapping and presents many practical suggestions on trap use.

Bateman (1973), has produced a general book on trapping which pictures and discusses many types of traps. Where large scale trapping programs are used markers and maps probably will be needed to enable workers to find traps easily and reduce trap losses. Numbers should be scratched into the metal or wood surfaces of the traps and records made of trap positions and numbers.

Traps that will capture more than one mouse at a time are available for use where mouse populations are high. However, these multi-catch traps all capture the mice alive. Frishman (1982) describes how to use these traps and indicates they are useful when placed outdoors near entrances to food processing establishments to catch mice before they enter the buildings. Traps can be immersed in water to kill captured mice. Such traps must be inspected and emptied every one or two days otherwise mice will cannibalize each other, creating odor and other problems. Wildlife managers or others may find these traps objectionable for this reason.

Glue boards, sticky box traps or tubetraps also can be used effectively in many locations. No data is available comparing efficacy of glue boards or boxes, with snap traps. However it is commonly known that glue traps catch small mice as well as large adults. (Rats are more difficult to capture with glue boards because they can sometimes pull themselves from the glue.) Such traps are easy to place but like snap traps require follow-up in order to prevent unsightly and odoriferous decomposition.

If glue boards are baited, the bait (e.g. peanut butter, jam, nutmeats, cake crumbs or sweets) should be placed in the center. Enclosed glue boards guard against moisture and dust, but may reduce the effectiveness of the board since mice are more cautious when entering an enclosed "new object". Keep boards in place for at least five days to allow mice to overcome initial shyness of the new object. Live animals stuck in the glue can be submerged until dead (NPCA, 1978). Some people regard glue boards as objectionable because they do not kill immediately. Also, if forgotten they can produce odors after death of a rodent.

Repellent sound devices have captured the imagination of consumers. No research is available to indicate their utility at this time. There is no information on their effects on other mammals. Any effects in repelling mice by such devices are likely to be short-lived if habitat modification also does not occur.

Dentition, stalking behavior, skeletal structure and stomach content analyses of the domestic cat, Felis cattus, indicate a high degree of adaptation specifically to killing house mice (Beadle, 1977). However, depending on the individual cat, they also will catch small reptiles, ground-nesting birds and insects. Therefore, outside of highly urbanized areas where they primarily patrol building interiors such as warehouses, their impact on wildlife may be detrimental.

4. Management Alternatives - Chemical:

Suppression of large mouse populations with chemical controls should be secondary to trapping with snap or sticky traps. However, where trapping or physical changes have been shown to be ineffective, chemical controls may be used. Baits containing Chlorophacinone or Fumarin are the chemicals recommended for NPS use.

Some poison-containing baits used for rat control (except red squill and norbormide) also can be used against mice. However, because mice nibble rather than eat large quantities at a time, a higher concentration of the poison is needed (Ebeling 1975). This requires proportionally more care by the pest control operator to prevent exposure of poisons to humans, pets and wildlife, particularly with single dose materials like zinc phosphide.

Because they are less hazardous to humans and wildlife the multiple dose anticoagulant poisons are preferable for house mouse control. These anticoagulants prevent blood clotting, causing rodents to bleed to death internally. An attractant or bait (usually a food item), is the key to the anticoagulant formulation since it both masks the poison and attracts the rodent. To prepare impregnated baits, an acceptable solvent is needed. Glycerine, corn, arachis and mineral oils were found to be more palatable than olive, linseed or cod-liver oil, see Rowe et al. (1974).

The multiple-dose anticoagulants, i.e. Warfarin, Chlorophacinone, and Fumarin are relatively safe for the operator and other humans. However, widespread resistance to warfarin has developed (see Kaukeinen 1979, for a list of references to anticoagulant resistance).

The warfarin-resistant micehave also shown resistance to chlorophacinone and tolerance to the newer single-dose anticoagulants, brodifacoum and bromadiolone. The rapid development of cross-resistance to these newer single-dose materials is significant. Frishman (1982), summarizing data provided by S.C. Franz indicates that in some areas of the U.S. (e.g. Buffalo, N.Y.) resistance to warfarin within some house mouse populations exceeds 75%. One can expect mouse resistance to follow the pattern already well-documented by the Rattus spp., i.e. house mice will become more difficult to control as resistance becomes more widespread.

Resistance to baits should be suspected if bait blocks (i.e. poison in parafin blocks, bait packages or loose bait regularly is eaten without a corresponding reduction in mouse sighting, holes or other signs of mice presence (see Howard and Marsh 1981). Laboratory verifications of resistance is the best procedure to use in evaluating the extent of resistance in a local population (Franz 1979).

The use of traps alone or in conjunction with poisons increased emphasis on preventative habitat maintenance and habitat alterations will help extend the useful life of existing poisons. Efforts to make existing poisons or poisoning procedures more effective also may reduce the speed of resistance development.

Bohills et al. (1982) present the results of studies to evaluate the design of mouse bait boxes. Bait boxes offer advantages over broadcast delivery systems because the bait is protected from the elements and inadvertent human and pet exposures. Also, the amounts taken can be monitored more accurately. These authors also indicate that the use of boxes significantly increases the take of food. By exposure to greater amounts of the toxicants per unit of exposure, marginally susceptable rodents are eliminated from the breeding population. However useful in the short term, such approaches do not directly address the problem of developing resistance.

All pesticides are labelled for specific uses by the U. S. Environmental Protection Agency. All label instructions must be strictly followed.

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NATIONAL PARK SERVICE
IPM Information Package

MUSEUM PESTS: DERMESTID BEETLES; CLOTHES MOTH; CASE MAKING MOTH

Final Report

5 January 1985

Submitted To:

Gary Johnston
U.S. National Park Service
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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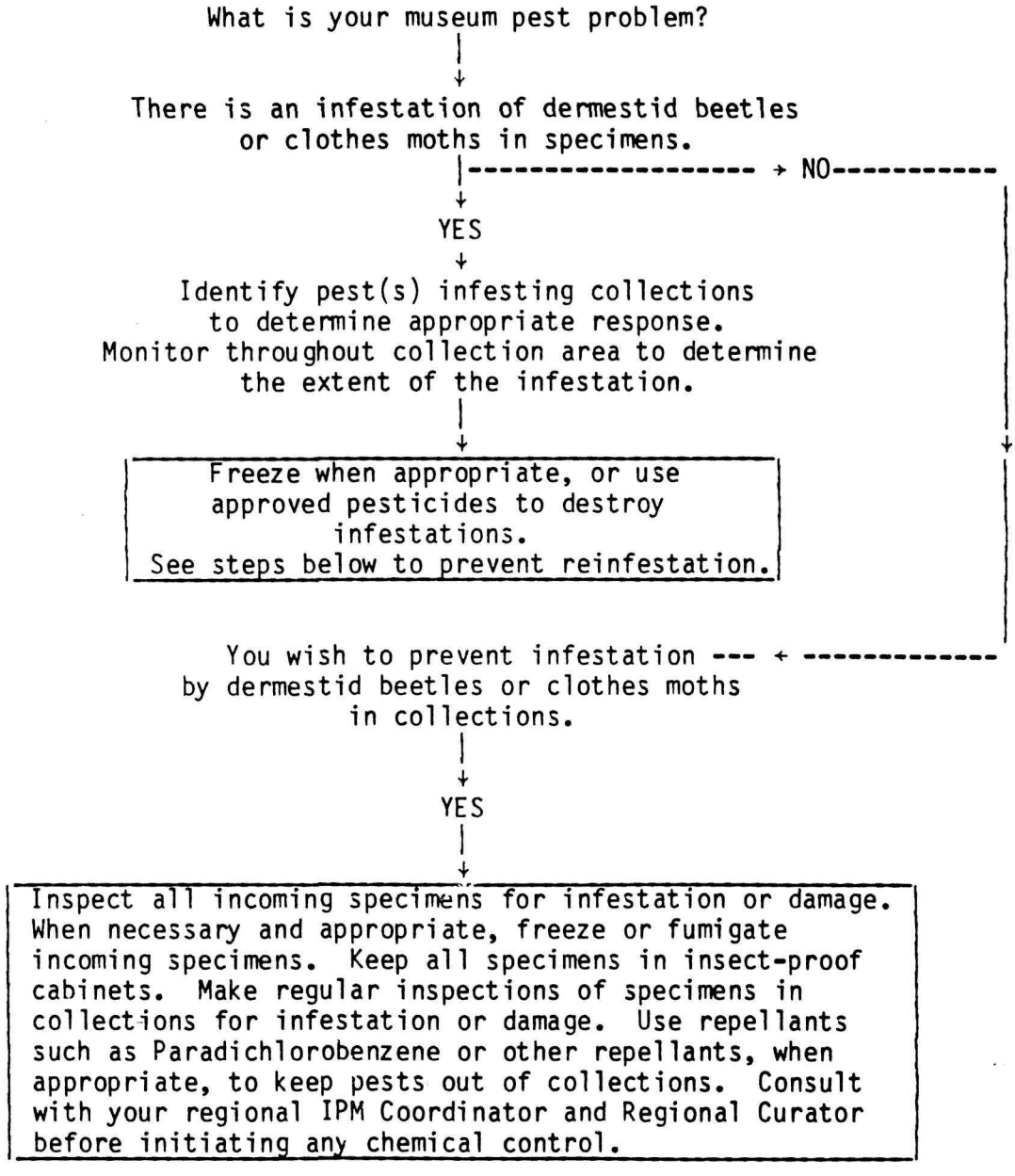
I. MUSEUM PEST IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All uses of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. MUSEUM PEST BIOLOGY AND ECOLOGY

1. Species Described:

Major pests of proteinaceous museum specimens are members of the beetle family Dermestidae (carpet beetles or dermestids), and moths in the family Tineidae (clothes moths). Three species of beetle and two species of moth are the most common museum pests, cause the most damage to specimens, and are the most difficult to control (Ebeling, 1975).

1. Black Carpet Beetle - Attagenus unicolor Brahm. Adults are 2.8 - 5 mm long, dark brown or black in color. Larvae are 7-8 mm long and narrow. They are dark brown to golden in color, with short bristles covering the body, and a "tail" of long bristles.

2. Common Carpet Beetle - Anthrenus scrophulariae (L.). Adults are approximately 5 mm in length, oval in shape, blackish with white scales, and a longitudinal stripe of orange and red scales down the middle of the back. Larvae are red to brown with black to brown hairs. They are 2.5-3.5 mm in length.

3. Varied Carpet Beetle - Anthrenus verbasci (L.). Adults are 2-3 mm in length, blackish with irregular white, brown, and yellow scales in a variety of patterns. Larvae are 4-5 mm in length, with tufts of bristles on each segment, and a "tail" of long bristles.

4. Webbing Clothes Moth - Tineola bisselliella (Hummel). Adults are golden yellow with a tuft of bronze colored hairs on the head, and a wingspan of 8-10 mm in length (females larger than males). Larvae are whitish, 8-10 mm in length.

5. Casemaking Clothes Moth - Tinea pellionella L. Adults are brownish with 3 dark spots on each front wing, 7-9 mm in length. Larvae are white, 7-8 mm in length.

See Mallis (1982), Beal (1970), Ebeling (1975), and Edwards, Bell, and King (1981), for illustrations, descriptions, and keys to these and other museum pest species.

2. Geographic Distribution:

1. Black Carpet Beetle - Worldwide distribution. Common throughout the U.S. and Canada, this species is the most important dermestid species in the states east of the Rockies.

2. Common Carpet Beetle - Worldwide distribution. Common throughout the U.S. and Canada, this species is the most common dermestid species in Rocky Mountain, northern tier, and mid-western states (Ebeling, 1975).

3. Varied Carpet Beetle - Worldwide distribution. Found throughout the U.S. and Canada, this species is the most important dermestid species in the Pacific Northwest and California (Ebeling, 1975).

4. Webbing Clothes Moth - Worldwide distribution. This species is the most common moth pest in the U.S.

5. Casemaking Clothes Moth - Worldwide distribution. This species is less common in northern U.S. than webbing clothes moth; more common in the southern U.S. (Ebeling, 1975).

3. Habitat:

1. Black Carpet Beetle - Commonly found in bird nests outdoors. Indoors, found near windows and in or near larval food sources (see Section 4).

2. Common Carpet Beetle - Outdoors; found in nests of small mammals. Indoors; in or near larval food sources (see Section 4).

3. Varied Carpet Beetle - Outdoors; commonly found in wasp nests and bee hives, including honey comb (Ebeling, 1975). Indoors, in or near larval food sources (see Section 4).

4. Webbing Clothes Moth - Indoors only in U.S. Found in or near food sources (see Section 4).

5. Casemaking Clothes Moth - Indoors in northern U.S., may be outdoors in summer in South. An infestation due to moth larvae in owl pellets deposited in a church steeple has been reported (Mallis, 1982).

4. Hosts:

The larvae of dermestids and clothes moths are the destructive stage. They are among the few animals which can digest keratin, and keratin containing substances such as wool, fur, and feathers are preferred food materials. Larvae attack other fibers, especially if the fabrics are contaminated with urine, perspiration, beer, milk, or fruit juices. Adults feed on nectar and pollen, or do not feed at all.

1. Black Carpet Beetle - Outdoors, adults feed on pollen and nectar. Indoors, larvae have been observed to feed on the following: woolens, including clothes and rugs; silk fabrics; carpets; felts; fur; skins; yarn; velvet; feathers; hair-filled cushions; meats; leather; museum specimens (including insect collections); spices; seeds; grains; and cereals.

2. Common Carpet Beetle - Outdoors, adults feed on pollen and nectar. Indoors, larvae feed on the following: fabrics; woolens; feathers; leather; fur; silk fabrics; mounted animal and pinned insect specimens in museums; and pressed herbarium specimens.

3. Varied Carpet Beetle - Outdoors, adults feed on pollen and nectar. Indoors, the larvae have been observed to feed on the following: woolens; skins and leather; fur; mounted museum specimens (especially insect specimens); feathers; horn; baleen, bone; hair; silk; plant material; and spices such as Cayenne pepper. Outdoors, this species is commonly found in wasp nests where the larvae feed on dead insects and other wastes (Ebeling, 1975).

4. Webbing Clothes Moth - Larvae feed on hair, feathers, fur, wool, upholstered furniture, piano felts, natural bristles, and lint. Adults are not believed to feed.

5. Casemaking Clothes Moth - Larvae feed on hair, hides, wool, feathers, and some plant material such as stored tobacco, herbarium specimens, drugs, and spices. Adults are not believed to feed.

5. Life Cycles:

1. Black Carpet Beetle - Eggs are laid indoors in lint, trash, or near other food sources. They hatch in 6-11 days at room temperature, longer if temperatures are lower. Larvae go through 5-11 instars under normal conditions, up to 20 if conditions are poor. The larval period takes approximately 260-640 days depending on availability of food, the level of humidity, and temperature. Larvae are repelled by light. Larvae pupate in the skin of the final instar. Pupation takes 6-24 days, longer in cold conditions. The adult may remain in the partially shed pupal skin for up to 3 weeks. Adults live only a short time; females live 30 days or slightly longer, males up to 40 days. Females lay from 40 to 115 eggs. There is 1 generation per year.

2. Common Carpet Beetle - Eggs are small and white, with projections at each end to catch and cling to fibers. Eggs hatch in 10-18 days. Larvae go through 6 instars, taking approximately 11 days per instar. Pupation occurs in the skin of the last instar and lasts about 2 weeks. After emerging, the adult is quiescent in the skin for approximately 3 weeks, then emerges and is active for approximately 30 days. Females lay up to 35 eggs. There is one generation per year outdoors, with overwintering in the pupal form. Indoors, several generations per year may occur.

3. Varied Carpet Beetle - Eggs are oval in shape, up to .55 mm long, changing in color to cream as they mature. Eggs hatch in 17-18 days under normal indoor conditions. Larvae go through 5-16 instars depending on availability of food, levels of humidity, and temperature. The larval period lasts from 1-2 years. Pupation occurs in the skin of the final instar, and lasts 10-13 days. Adult males live 2-4 weeks, females, 2-6 weeks. There is a single generation per year outdoors, but several per year indoors.

4. Webbing Clothes Moth - Eggs are oval, white, 1 mm in size. They are laid singly or in small groups among loose threads in most natural fibers or among hairs in furs. Eggs hatch in 4 days to 3 weeks, depending upon temperature; 4-10 days in summer, longer in winter. Each female averages 40-50 eggs, with some females depositing up to 150.

Larvae are 1 mm long when first hatched, and whitish in color. There are 5-11 instars, depending on temperature and availability and quality of food. The larval stage lasts from 1-29 months. Larvae often spin silken pads (webs) or construct silken feeding tubes on the feeding surface. Larvae are nocturnal. Indoors, pupation lasts 8-10 days in summer (21-28 days in winter in cooler buildings). Adult males live an average of 28 days, females, an average of 16. Life spans are longer at lower temperatures where metabolic processes are slower. Females mate once and begin to oviposit on the same day they emerge from the pupal case. After laying their full compliment of 40-50 eggs, females die. Males mate throughout their adult lives. Males are moderately strong fliers; gravid females walk, but will fly if disturbed. Adults do not fly to light, and will avoid lighted areas.

5. Casemaking Clothes Moth - The life history of the casemaking clothes moth is similar to that of the webbing clothes moth. The larva spins a case of silk and fibers from the food source. The colors of the food source will be represented in the case. This case is carried with the larva throughout its life; the larva will die if removed from the case. The case is 6-9 mm in length, depending on the instar and size of the larva. Larvae graze at random over the food surface; damage is proportional to the time spent in any one area. Larvae are nocturnal. Pupation occurs within the larval case in a protected place.

   There are 2 generations per year in the South, 1 in the North. In the northern U.S., adults are often seen flying between June and August. Adults do not fly to light.

6. <u>Seasonal Abundance:</u>

1. Black Carpet Beetle - Outdoors, most abundant from April to June. Adults are not found after July. Indoors, most abundant from February to July, but can be found at any time under suitable conditions.

2. Common Carpet Beetle - Outdoors, adults are most common in late May to June when they feed on pollen and nectar. Indoors, adults and larvae may be common all year in heated buildings.

3. Varied Carpet Beetle - Outdoors, adults are most common in late spring and early summer when they feed on pollen and nectar. Indoors, adults and immatures may be common all year in heated buildings.

4. Webbing Clothes Moth - Indoors, in heated buildings, webbing clothes moths are active throughout the year.

5. Casemaking Clothes Moth - Indoors, in heated buildings, casemaking clothes moths may be active and breed throughout the year.

6. Response to Environmental Factors:

Populations of museum pests are influenced by temperature, humidity, and the availability of food. Humidity, rather than temperature, is thought to be the most critical factor after food. This factor is currently under study.

8. Impact of Museum Pests:

8.1 Direct Impact:

Carpet beetles and clothes moths feed on a wide variety of museum specimens, damaging or ruining their scientific, aesthetic, and historical values. The varied carpet beetle may also infest foodstuffs such as cereals and other grain products.

8.2 Indirect Impact:

Some species of dermestids may bore through cardboard or paper containers, allowing access by other insect pests.

9. Natural Enemies:

Dermestids and clothes moths are preyed upon by other insects, mites, and spiders. Eggs may be destroyed by fungi at high humidities. However, high humidity and fungi create other management problems.

III. MUSEUM PEST MANAGEMENT

1. Population Monitoring Techniques:

Specimens on display, as well as all collections, should be monitored on a regular (at least twice a year) basis for dermestids and moths. Use a handlens to examine for eggs if an infestation is suspected. Look for live adults and larvae, and the presence of cast larval skins or sand-like feces which are often the color of the substance being fed upon (dermestids only). Presence of feeding debris around or below specimens is an indication of infestation. Exit holes, feeding holes, hair falling from fur or pelts, mats of fibers under which clothes moth larvae feed, silken feeding tubes, silken larval cases, or moth pupae are all indications of infestation.

Examine window sills on a regular basis as many of these insects fly to the light in search of outdoor flowers and nectar. Larvae may also be found behind baseboards, mouldings, in cracks in floors, behind radiators, or in air ducts. Small sticky boards (3" x 5" cards) randomly placed throughout the facility and/or specimen cases, and routinely examined are useful in detecting early infestations.

Rountine examination and frequent movement of articles, if possible, will also disrupt insect populations and detect infestations.

Damaged materials can be examined under a microscope to determine the species responsible (Pence, 1966).

2. Threshold/ Action Population Levels:

Presence of live adults or larvae indicate ongoing infestations which should be treated immediately. Cast larval skins and feeding damage may have resulted from old infestations, but in regularly monitored collections, this should be regarded as an indication of an active infestation. Thus it is vitally important to maintain careful monitoring records.

3. Management Alternatives - Nonchemical:

The most effective way to prevent damage from dermestids and clothes moths is to prevent establishment of infestations. All incoming specimens should be examined carefully for damage and live insects,and records kept. Incoming specimens showing signs of infestation

may be frozen at -18°C for at least 48 hours before being accessioned (Crisafulli, 1980). Freezing is not recommended for wood, bone, lacquer, painted surfaces, leather, and certain other specimens. Contact your Regional Curator before undertaking any control measures.

All specimens subject to insect damage should be kept in insect-proof cases if possible, and examined on a regular basis.

Lowered humidities and, to lesser extent, lowered temperatures reduce the chance of infestation. Infestations may slow or stop during winter when indoor humidities are their lowest. Under conditions of extreme humidity, dermestid eggs may be attacked by fungi (Mallis, 1982), however humidities high enough to promote fungal growth may be damaging to most specimens. Low humidities may shrink or otherwise damage some specimens.

Windows in areas where specimens are kept should be tightly screened or kept closed at all times to prevent entry by dermestids. Adult dermestids feed on pollen and nectar and cut flowers should be kept out of specimen areas to reduce the chance of accidental infestation.

All air vents and hot air registers should be equiped with filters to trap potential incoming pests. Filters should be changed on a regular basis. All preparation of specimens should take place in areas other than collection rooms.

Vacuum all accesible areas on a regular basis to prevent accumulations of lint, hair, and other carpet beetle and clothes moth food materials.

Research is ongoing concerning the use of B.t. and IGRs for control of museum pests.

4. Management Alternatives - Chemical:

Consult your regional IPM coordinator and Regional Curator to determine which pesticide, if any, is best suited to your IPM program.

Care should be taken when using chemical pesticides, as materials may be hazardous to human health and may damage some specimens.

Paradichlorobenzene and naphthalene are commonly used as repellants in museum cases. These materials do not eliminate infestations, but may be useful in preventing them. Paradichlorobenzene and naphthalene may cause damage to certain plastics (e.g.; bakelite), and may soften and shrink resins, adhesives, and paints. Organic gas filters should be installed on the sides of cabinets to absorb fumes and replaced when the odor is detected in the room.

Dowfume 75 (a mixture of carbon tetrachloride and ethylene dichloride) is used as a fumigant against dermestids and moths. A highly toxic chemical, it should only be used by qualified personnel in fumigation chambers which are inspected often. Manufacture of homemade Dowfume 75 is extremely dangerous and clearly illegal. Dowfume-75 may soften paints and resins.

For emergency use on wooden specimens which are too large to move, vapona strips may be used as a fumigant when placed with the specimen under a plastic tarp for approximately 5 days. It is no longer recommended for use in museums and is listed as unsuitable for this purpose by its manufacturer. It is considered minimally effective for use against insects. Vapona undergoes hydrolysis in the presence of atmospheric moisture (the % relative humidity needed to trigger hydrolysis is unknown), and releases sulfuric acid vapors which soften gums and resins, corrode metals, and weaken cellulose. Vapona strips now being used should be removed to prevent damage to specimens.

Pyrethrum may be used in storage cases as a contact pesticide. The material should not be allowed to contact specimens.

Vikane as a structural fumigant in buildings, under tarps, or in cabinets may be used to destroy infestations. Vikane may be applied only by licensed fumigators. It may contain additives such as chloropicrin to allow detection in the case of leaks. Additives may be damaging to some specimens.

The following insecticides are not yet registered for use in museums, but their use is not inconsistent with the labelling:

Drione powder or aerosol is effective on most insect pests in herbaria for up to 6 months. It is used in cases as a contact insecticide, but should not contact specimens.

Ethylene oxide fumigation has occasionally been used in instances where other methods have failed. Ethylene oxide is not recommended in most cases due to the hazards involved in application of the chemical, with 1 ppm the maximum safe limit (detection at 1 ppm requires equipment not normally available to most museums; the human nose can detect this material at approximately 70 ppm). Ethylene oxide is an active carcinogen. Use of ethylene oxide now requires special fumigaton chambers and other safety precautions. Ethylene oxide adheres to fibers and off-gasses for considerable periods.

5. Summary of Management Recommendations:

1. Inspect collections on a routine basis for signs of infestation and damage. Record all data.
2. Isolate collections from public areas, preparation areas, and from dermestid colonies used in specimen preparation.
3. Inspect all incoming specimens for signs of infestation.
4. All incoming specimens should be quarantined and if appropriate, frozen or fumigated.
5. Where appropriate, use repellents such as paradichlorobenzene to keep dermestids and clothes moths out of collections.
6. If infestation is observed, use of an approved pesticide may be required.
7. Check with Regional IPM Coordinator and Regional Curator prior to initiating any control program.

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NATIONAL PARK SERVICE
IPM Information Package

PEST BIRDS:
PIGEONS, STARLINGS, HOUSE SPARROWS

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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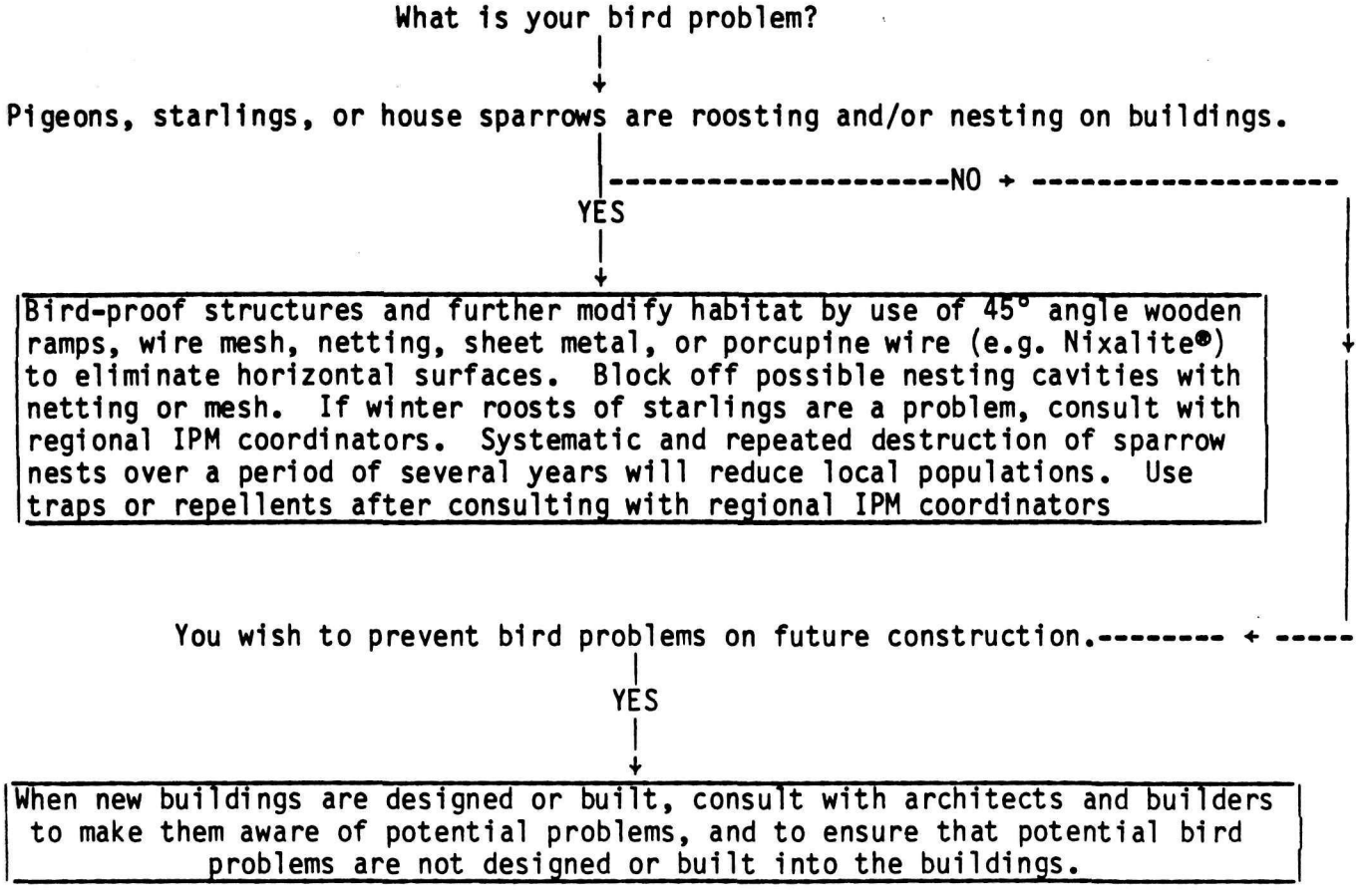
I. PEST BIRD IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. BIOLOGY AND ECOLOGY OF PEST BIRD SPECIES

1. Species Described:

Three birds: pigeons, starlings, and house sparrows are considered common pest species and all are exotic species.

A. Feral pigeon or rock dove - (*Columba livia*)

B. Starling - (*Sturnus vulgaris*)

C. House or English sparrow - (*Passer domesticus*)

See pages 179-180, U.S. Department of Health, Education, and Welfare (1967), or any field guide to American birds for illustrations and descriptions.

2. Geographic Distribution:

A. Pigeons were introduced into North America as a food animal in the early 17th century. Feral pigeons are found throughout North America, especially in urban areas and on farms. In Eurasia, the ancestral bird (rock or blue dove) is found along coasts and in rocky areas (Marsh and Howard, 1982).

B. Starlings were introduced into New York City in the 1890's. They are now found throughout the U.S., including Alaska and Hawaii.

C. House sparrows were introduced into North America in 1850. They are now found throughout the U.S. in cities and on farms.

3. Habitat:

A. Feral pigeons nest commonly on building ledges, roofs, cliffs, or in caves.

Pigeons are attracted to cities by the availability of habitat and by abundant food sources such as spilled grains, garbage, and other foods.

Adults eat about a pound (1/2 kg.) of food each week. Pigeons eat seeds, grains, and other vegetable materials, some insects, animal manure, garbage, and grit.

B. Starlings nest in natural or man-made cavities.

Starlings often roost in cities in winter, attracted by sources of warmth such as heat

vents. They feed away from their roosting sites. They sometimes flock in numbers that disrupt surrounding areas.

Adult starlings are insectivorous to omnivorous, feeding on insects, fruit, and grains.

C. House sparrows originally were found primarily in cities where they fed on undigested grain in horse manure. With the increased use of the auto, they have shifted their diet to include more insects, seeds, and foodstuffs discarded by humans.

House sparrows nest on any elevated semi-protected spot such as gutters, rafters, or ledges.

Adult diets consist of insects, and a variety of seeds, grains, fruits, and buds.

4. Hosts: Not applicable.

5. Life Cycles:

A. Pigeons - Breeding occurs year round but peaks in spring and summer.

Nests are crude and flimsy platforms about 1 foot in diameter constructed from sticks, grasses, and twigs. One to two white eggs are laid in each nest. One adult pair may raise several broods in a single season. Eggs are incubated by both parents, and require 17-19 days to hatch. Young birds (squabs) are fed "pigeon milk" (predigested food) from the adult crop. Young fledge in 35-37 days. Eggs of the next brood are often laid before the existing brood is weaned and fully fledged. Pigeons are monogamus and mate for life.

Pigeons commonly live for up to 15 years, and occasionally up to 30 in captivity. In the wild, mortality rates are approximately 33% per year in adults, and nearly 50% per year in juveniles. Only about 1/3 of the adults reproduce each year.

B. Starlings - Starlings mate in spring and lay 3-8 eggs per clutch.

Starlings are cavity nesters. There are 1-3

broods per year. Nests are made of fiberous materials and lined with soft material such as grass, down, or feathers. Incubation lasts for approximately 12 days. The young are fed primarily on insects by the parents. The young fledge in 2-3 weeks after hatching. After fledging, young birds form small flocks which coalesce as the season progresses to form large roosting flocks, numbering up to several thousand individuals.

C. House sparrows - The peak breeding season is spring, but broods are produced throughout the warm months (late April to October).

Nests are usually constructed near each other, and are made of twigs, grass, paper, and string. House sparrows lay 3-8 eggs per clutch. Incubation lasts 11-17 days, and the young fledge in about 2 weeks. Young are fed on insects by the adults. Mortality rates for young in their first year is over 50%.

6. Seasonal Abundance:

As with other birds, populations of pestiferous species peak in late summer when all broods have fledged and before seasonal mortality factors (shortage of available food, drinking water, and cold, wet weather) have begun to make themselves felt.

7. Response to Environmental Factors:

Cold, wet winters and springs are major causes of bird mortality, espcially when combined with lack of food and available water.

8. Impacts of Pest Bird Species:

8.1 Direct Impact:

The most obvious direct impact of pest birds is the noise and debris they produce. Bird droppings can deface statuary and masonry. Bird excrement may also kill lawns and shrubbery when it becomes too abundant, and will cause objectionable odors. Droppings and nests attract pest insects such as roaches and carpet beetles. Nests obstruct drain pipes, mar windowsills, interfere with awnings, and create hazardous footing on fire escapes. Bird droppings, feathers, and nesting materials may create fire hazards, obstruct chimneys, and often contaminate grain. Large quantities of grain may be consumed by birds that live

around grain-handling establishments (Ebeling, 1976).

Starlings and, to a lesser extent, house sparrows are believed to be largely responsible for the decline in the populations of several native species of cavity nesting birds including the eastern bluebird and red-headed woodpecker.

8.2 Indirect Impact:

Pest birds may spread diseases to humans or livestock through droppings or by droplets from respiration.

A. Pigeons - Pigeons have been demonstrated to carry pigeon ornithosis, which causes psittacosislike symptoms which are usually mild in humans. Pigeons are known carriers of encephalitis viruses; aspergillosis, a fungus disease of the human ear sinuses, lungs, or skin; and "thrush", a fungal infection of the mouth, respiratory system, urogenital tract, skin, or fingernails. Pigeon manure may harbor spores of the fungus which causes histoplasmosis; in one study, it was found that children living in buildings where pigeons nested had an infection rate 3 times that of children living in pigeon-free structures (Ebeling, 1975). Pigeons also harbor Newcastle disease, a highly contagious and fatal virus of domestic fowl, and are implicated in the transmission of hog cholera (Ebeling, 1975).

B. Starlings - A high incidence of positive tests for histoplasmosis has been found in persons living near starling roosts (Marsh and Howard, 1982).

C. House sparrows - Due to the close association of house sparrows with human activities and the high rate of encephalitis antibodies found in house sparrows (an indication of long-term infection), this species is believed to be among the most important bird reservoirs for this disease (Ebeling, 1975).

9. Natural Enemies:

As with all birds, pest species are attacked by a variety of predators, parasites, and pathogens.

III. PEST BIRD MANAGEMENT

1. Population Monitoring Techniques:

Pest birds are monitored by visual inspection of numbers of individuals and of nesting and roosting areas.

2. Threshold/ Action Population Levels:

The determination of tolerable numbers of pest birds is difficult. The public, in general, interacts positively with birds (watching and feeding), especially in urban areas. Conversely, the public is annoyed by the nuisance caused by bird sounds in roosts, debris, and droppings. Park managers must determine what population levels are tolerable in their parks.

3. Management Alternatives - Nonchemical:

1. Pigeons - Sanitation, i.e., removal of food sources will greatly reduce the attractiveness of an area to pigeons. All spilled food or refuse should be removed on a regular basis. Persons who regularly feed pigeons in urban areas should be approached and dissuaded from feeding, or asked to cut back on the amount of food fed. Sanitation programs aimed at rats will also reduce the amount of food available for birds. Nest and nest site removal should also be included in a sanitation program. Nest removal may be particularly useful in sparrow control programs, but must be combined with other measures such as bird proofing to have long term effects.

   Buildings should be bird-proofed to prevent roosting and nesting by pigeons and sparrows. Openings in buildings, and horizontal roosting and nesting surfaces should be screened off with 1/2 inch-mesh rust proof wire or commercial bird netting. Ledges should be fitted with wooden ramps, sheet metal, or plexiglass forming a 45° angle to prevent roosting or nesting. Ledges and window sills should be fitted with porcupine wire such as Nixalite® to prevent roosting. Porcupine wires should be inspected periodically to remove any accumulatin of debris which may provide suitable roosting and nesting surfaces. Cables, such as those used in roof supports, should be fitted with 25 gauge (.059 inch diameter) music wire 3 inches above the cable, and held in place by brackets and clamps to prevent roosting (Manski, 1982). In cases where historic buildings are involved, the

historic integrity of structures should be preserved; consult with the regional historian before structural modifications are undertaken.

Frightening devices are ineffective for pigeons, which rapidly habituate to devices such as plastic owls and snakes. Changing positions of devices may serve to lengthen the habituation period. Auditory repellants, such as fire crackers or recorded alarm calls, are also habituated to in a short time.

Trapping has been used with success in reducing or removing pigeons, especially when numbers are small. See Marsh and Howard (1982) for details on types of live traps available. Any native birds or privately owned banded pigeons which have been trapped should be released. The rest should be disposed of in a humane manner.

Before any trapping program is begun, check with your regional IPM Coordinator to determine regulations and permits required.

2. Starlings - The same management methods used for pigeons are effective for starlings. Openings in buildings should be sealed where appropriate. When large flocks of starlings are roosting in trees, selective pruning to open the canopy and to make tree cover unsuitable for roosting is often effective.

3. House sparrows - Management methods for pigeons are also effective for house sparrows. Nest destruction may be useful in population reduction due to the relativly high yearly mortalities in sparrow populations (over 50%). Nest destruction must continue for 2 or more years before any effect is seen, and without habitat modification (screening, exclusion, etc.), the area will be recolonized from other, nearby populations in a short time.

4. Management Alternatives - Chemical:

Chemicals used in bird control may be divided into 3 groups: repellents, chemosterilants, and lethal agents. The later 2 groups are not recommended for use in NPS areas.

Repellents - Sticky repellents cause birds to avoid roosting in areas where they have been used. Although effective, tackiness is lost

in time due to dust accumulation. Sticky repellents are commercially available in gel form in cartridges, squeeze tubes, and aerosol cans.

Chemosterilants - In theory, chemosterilants reduce local populations by inhibiting reproduction and allowing mortality factors to act upon and reduce flock size. Chemosterilants in bait, when fed upon repeatedly, inhibit female fertility. To be fully effective, chemosterilants must by used on an area-wide basis due to immigration of non-sterile adult females from adjacent areas.

Lethal agents - A chemical frightening agent, 4-aminopyridin, is used at feeding sites to frighten birds away from these areas. It is available in a bait formulation, but is increasingly opposed on humane grounds. Frightening agents are lethal to birds which have consumed quantities of bait, but are slow acting. Prior to death, the affected birds display erratic behavior and emit distress cries which frighten other members of the flock into leaving the area. Generally, frightening agents are not effective on sparrows or pigeons due to less well developed communications systems of these species. See Marsh and Howard (1982) for details.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Prior to design or building of structures, consult with architects and builders to aviod designing or building suitable habitat in the structure.

2. Birdproof structures to prevent nesting and roosting. Birdproofing devices can be fabricated to blend in with the structure.

3. Clean up spilled grains or other potential foods; use good sanitation practices.

4. If necessary, trap or use chemosterilants or registered avicides to reduce populations in conjunction with the above measures. (Birdproofing will keep the area free from colonizing birds from other areas).

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NATIONAL PARK SERVICE
IPM Information Package

POISON IVY

Final Report

February 1984

Submitted To:

Dr. Michael Ruggiero
Biological Resosources Division
National Park Service
Washington, D.C.

Submitted By:

John Muir Institute
743 Wilson Street
Napa, California 20852

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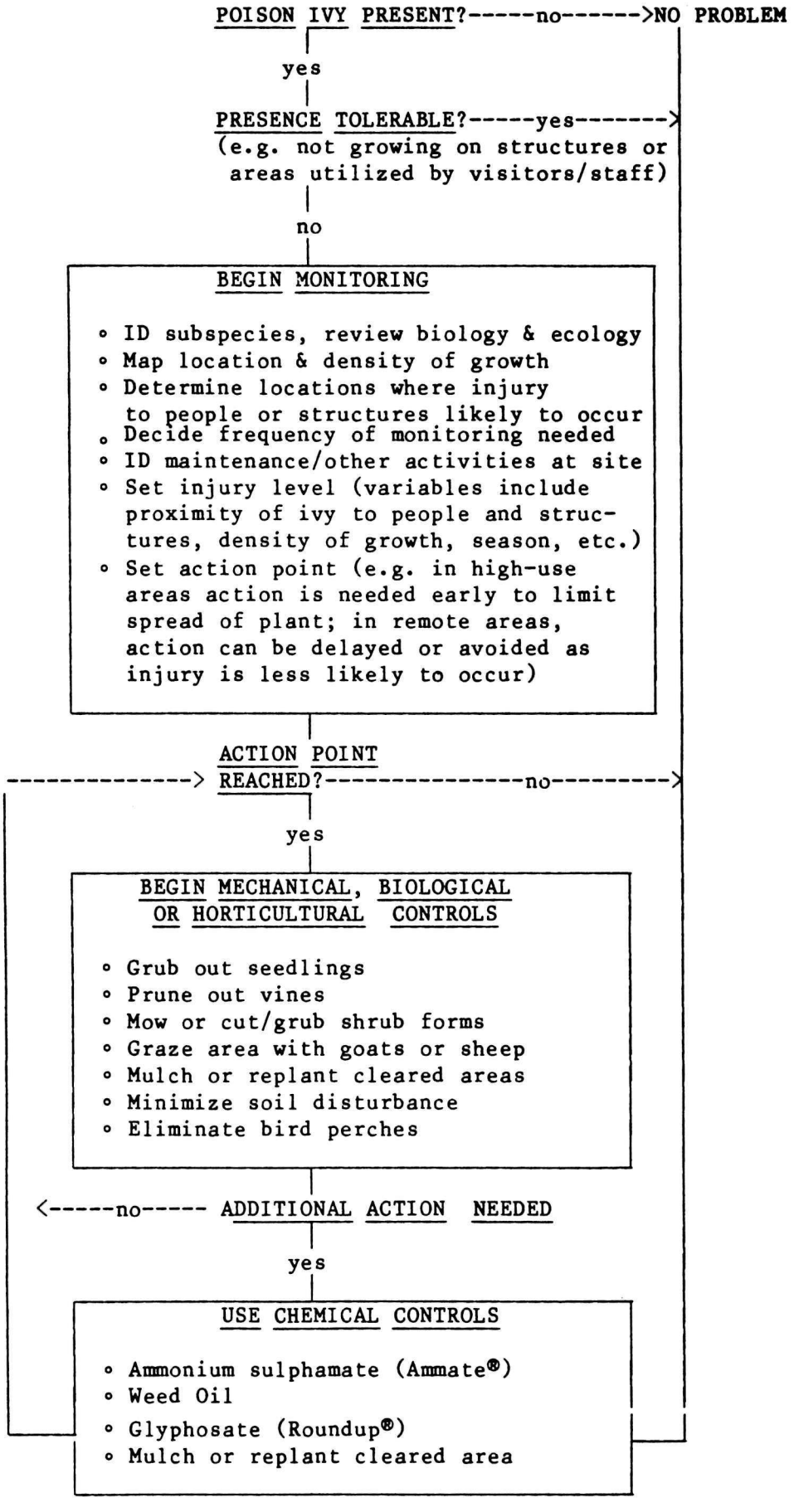
I POISON IVY IPM DECISION TREE



II BIOLOGY AND ECOLOGY OF POISON IVY

1. Species Described:

Poison ivy is a member of the Sumac family, Anacardiaceae, which also contains such familiar plants as Poison oak (Rhus diversiloba) and Poison sumac (R. vernix), the cashew nut tree (Anacardium occidentale), and the lacquer tree of China and Japan (Toxcicodendron vernicifluum) from which oriental lacquerware is made. The sap in each of these species contains urushiol which can cause severe dermatitis in susceptible humans.

Poison ivy (Rhus radicans L., or Toxicodendron radicans Kuntz) is a deciduous woody perennial plant which is native to North America. It takes several forms including a trailing vine, a subshrub to shrub from 2 inches to 4 feet high, or a vine up to 50 feet tall

Leaves are 1/2 to 2 inches long, and are always borne in groups of three leaflets. These leaflets, found alternately along the stem, may be glossy or dull-green, are usually smooth, but occasionally may be somewhat hairy. The edges of the leaves vary widely, some are smooth, others are toothed or even deeply lobed. Unfurling leaves are red, becoming green during summer and colored various shades of yellow, orange, red or bronze in autumn.

Leaves of poison ivy never occur in pairs along the stem. This "alternate" leaf characteristic distinguishes poison ivy from other, more benign plants such as Virginia Creeper, Parthenocissus quinquefolia L., See Table 1 for details which distinguish poison ivy from plants which resemble it.

Stems are woody, ranging from ½ to 6 inches in diameter Slender, creeping rootstalks are produced from the base of the stem. These roots often travel horizontally on top of or through the soil, giving rise to short, slender leafy shoots several yards from the parent plant.

In early summer, small clusters of greenish-white flowers form where the leaf and stem join. Flowers develop into white or cream-colored berries about 1/8 inch in diameter. The berries are especially helpful in identifying poison ivy during the winter.

Consistent variation in the appearance and growth habit of poison ivy is recognized by the designation of certain subspecies. See Table 2 for a description and geographical distribution of the major subspecies of poison ivy.

TABLE 1.

DISTINGUISHING POISON IVY FROM PLANTS WHICH RESEMBLE IT

RELATED SPECIES	POISON IVY
Virginia Creeper (Parthenocissus quinquefolia) has leaves composed of five leaflets; leaf scars are circular with raised edge; fruits are juicy and purple; aerial roots contain suction disks.	Leaves are composed of three leaflets; leaf scars are triangular; fruits are hard and white; no suction disks on aerial roots.
Boston Ivy (Parthenocissus tricuspidata) has leaves with three lobes but rarely three leaflets; leaves are up to 8" wide; fruits are juicy and purple; aerial roots contain suction disks.	Leaves are composed of three distinct leaflets; leaflets are narrow, rarely exceeding ½ inch in width; fruits are hard and white; no suction disks on aerial roots.
Box Elder (Acer negundo) has leaves composed of three leaflets but are borne opposite each other on the stem; fruits are in flattened pairs with "wings"; young stems are bright green.	Leaves composed of three leaflets borne alternately on the stem; fruits have a round, berry-like shape; young stems brown or dull green.

2. Geographic Distribution: Poison ivy is widely distributed in the United States. Table 2 provides a description and gives the distribution of the four subspecies of poison ivy.

3. Life History: Poison ivy has male and female flowers on separate plants (dioecious). Pollen is distributed by insects and female flowers produce a high percentage of one-seeded mature fruit (Mulligan 1977). Seeds mature in late summer or early fall. They may remain viable for at least six years (Gillis 1971).

Few seeds fall directly to the ground, remaining instead encapsulated in the fruits which are eaten by birds and other wildlife.

Poison ivy also reproduces from alternate buds on horizontal rootstalks. However, horizontal spread of poison ivy is slow, rarely more than 4 inches/year and frequently less (Mulligan 1977). However, vertical growth of vining stems is rapid. Despite its ability to propagate vegetatively, poison ivy rarely becomes established by plant fragments (Gillis 1971).

Colonization of new sites is primarily by seed dispersed by birds and animals during autumn, winter and early spring. The hard seeds pass through the digestive tracts of birds and animals in a viable condition.

Seeds germinate when the soil warms up in the spring. They produce a primary vertical stem and basal roots. Horizontal rootstalks (rhizomes) are produced from the base of the primary vertical shoot in the first or second growing season, and grow horizontally on or beneath the surface of the ground. Rhizomes have buds which produce new vertical stems as well as adventitious roots just below each bud. Each new vertical stem in turn produces additional horizontal rhizomes, resulting in a large interconnected clone with many vertical stems and horizontal rootstalks, both above and below ground.

Flower and leaf buds are formed on new growth on vertical stems in late summer and early autumn, and are carried overwinter on the stems. Flower buds formed the previous year open in late spring through mid-summer, depending on location. Maximum flowering occurs in June and July in most areas with some additional flowering occuring sporadically until early autumn.

TABLE 2. MAJOR SUBSPECIES OF POISON IVY FOUND IN THE UNITED STATES

Latin Name	Description	Distribution
Rhus radicans L. subsp. radicans (Toxicodendron radicans subsp. radicans Green, Mulligan.)	Shrub to vine form with aerial roots climbing rough surfaces; undersurface of leaflets with tufts of hairs toward bases of midribs; hairs ascending along lateral veins on undersurface of leaflets; usually 5 or more leaves on vertical stems; leaflets entire or mostly entire; surface of fruits pubescent.	A lowland subspecies which is essentially an Atlantic coastal dweller that occurs from southern Nova Scotia south to the Florida Keys and the western Bahama Islands and west to eastern Texas. It is separated from subsp. negundo to the west by the Allegheny Ridge in PA. and NY., and the Blue Ridge mountains to the south. In the north R. radicans is separated from R. rydbergii along the 44th parallel of latitude.
R. radicans L. subsp. negundo (T. radicans, subsp. negundo Greene).	Shrub to vine with aerial roots climbing rough surfaces; hairs along midrib on undersurface of leaflets not tufted; hairs along sideveins on undersurface of leaflets spreading; usually 5 or more leaves on vertical stems; leaflets toothed or mostly toothed.	Found in the central area of the U.S. (the midwestern states generally north of the Ohio River). Eastern boundary is Allegheny Ridge, most clearly delimited in the vicinity of Tuscarora Mountain in Pennsylvania. On the east flank of the Alleghenies is subsp. radicans.
R. radicans L. subsp. rydbergii (T. radicans, subsp rydbergii Greene)	A trailing vine, or a subshrub to shrub lacking aerial roots; hairs along midrib on undersurface of leaflets not tufted; hairs along sideveins on undersurface of leaflets spreading; usually fewer than 5 leaves on stems; leaflets toothed.	Most widespread and uniform of all the subspecies. Occurs from Central Arizona to the Gaspe Peninsula and to the Rockies in southern Canada.
R. radicans L. subsp. verrucosum (T. radicans subsp. verrucosum Greene)	Aerial roots; glabrous leaves and shoots except for an occasional population with small tufts of hairs in major vein axils on lower leaflet surface. Has become distinctive due to prominent sharp lobes on the leaflets.	Found only in Texas.

The vine form of poison ivy is the most common form and may grow to several inches in diameter and become woody. Slender vines may run along the ground, grow with shrubbery, or take support from a tree.

The vine forms roots readily when in contact with the ground or with any object that will support it. Aerial roots attach the vine securely to the tree or post. According to Crooks and Klingman (1967), the vines and roots apparently do not cause injury to trees except where growth may cover the supporting plant and exclude sunlight. The vining nature of the plant makes it well adapted to climbing over stone walls or on brick and stone houses. See Section II.2 for a discussion of the impact of poison ivy vines on buildings and other structures.

4. Hosts/Site Information:

Poison ivy is usually found where soils have been repeatedly disturbed. It does not grow where repeated agricultural cultivation occurs, since these operations remove seedlings before they can become well-established. Poison ivy grows in association with many other native and introduced plants and is most often found growing at woodland edges or openings, along roadsides and fenceposts, and adjacent to watercourses. Because poison ivy fruits are eaten by a wide variety of birds, the plant is common around trees, fencerows, under telephone wires, and wherever birds are likely to perch.

Its wide distribution throughout the north-and southeastern U.S. and extensions into Canada and south into Central America indicates that poison ivy is adapted to a wide variety of climatic conditions.

Poison ivy grows on a variety of soils. According to Gillis (1971), calcium is the most important element in the soil for the growth of poison ivy. The maximum root development is in the A horizon of the soil and poison ivy is virtually absent from soils that are highly leached of minerals, especially calcium and magnesium.

As a colonizer of disturbed soils, poison ivy appears to play a significant role in erosion control and soil stabilization. In the Friesland Province of Holland, poison ivy is used to stabilize dykes (Gillis 1975). In park settings, poison ivy (properly posted with signs) could be used to discourage human trampling of sensitive areas.

5. Natural Enemies:

Mulligan (1977) lists arthropods in the following orders as feeding on poison ivy: Lepidoptera, Hymenoptera, Diptera, Coleoptera, Homoptera (Aphididae) and Acarina (Harrison 1904; Tissot 1928, 1933; Steyskal 1951; Gillis 1971; Richards 1972). Criddle (1927) considered the larvae of Epipaschia zelleri Grote (Lepidoptera) the most destructive of all insects to poison ivy.

Conners (1967) lists the following fungi as infesting poison ivy in Canada: Cercospora rhoina Cke. & Ell. Man., Cylindrosporium irregulare (Pk.) Dearn., Cylindrosporium toxicodendri (Ell. & Mart.), Phyllosticta rhoicola Ell. & Ev., and Pileolaria brevipes Berk. & Rav. Parmelee and Elliott (1974) also list Pileolaria brevipes from British Columbia and Arthur (1934) states that this rust infects poison ivy throughout its range.

Fruits are eaten by many birds. Martin et al. (1951) report that poison ivy fruits make up a quarter of the diet of some flickers and wrentits. Fruits, stems and leaves are eaten by bears, muskrats, rabbits, small rodents and deer, and a number of small mammals use it for cover. Bees can make a nontoxic honey from its nectar (Rostenburg 1955).

III POISON IVY MANAGEMENT

1. Population Monitoring Techniques:

The environmental conditions conducive to poison ivy growth (e.g., sites where soils have undergone severe disturbance) should be monitored several times per season in order to spot new infestations of the plant. Examples of such areas include construction sites, trenching operations, heavily used trails, eroding streamsides, and even rodent mounds. Monitoring of these areas can consist of casual observation until poison ivy is found to be present, at which point written records should be initiated.

Begin monitoring in mid-to-late spring when new seedlings have germinated and the leaves have opened on older, established clumps. Use the distinctive 3-part leaves to identify the plant. To decide on levels of effort needed for monitoring, determine which growth form of poison ivy is present at the site. With the relatively low shrub forms which tend to spread horizonally only very slowly -- approximately 4" per year (Mulligan 1977), monitoring can be kept to a minimum.

The most important thing is to time the first monitoring visit(s) early enough in the season that both seedling and established poison ivy stands are visible and can be accurately noted on a map. This is usually mid-to-late May in most parts of its range.

For the vining forms of poison ivy which are capable of rapid and extensive vertical growth (six to twenty feet in one season is not unusual), more frequent monitoring might be desirable in order to determine the need for treatment before growth is excessive. Since most vertical growth of poison ivy occurs prior to flowering, it is desirable to monitor poison ivy vines once per month between foliation in the spring (April-May), and onset of flowering (June-July in most areas) and again at the end of the growing season.

If monitoring indicates that no treatment is required, subsequent visits should be necessary only at the end of the summer before plants lose their leaves. At this time any changes in park use patterns near the poison ivy, as well as the height and width of the clump can be recorded. By reviewing monitoring data park managers can determine relative growth rates of poison ivy in their area as well as the likelihood of park visitors or workers coming in contact with it. Decisions about injury (tolerance) levels and treatments can be based on this data.

If a treatment is warranted, monitoring must occur frequently enough to determine when the plants are at the optimal stage for treatment. For example pruning treatments on poison ivy are most effective if applied just before the plant blooms; herbicide treatments on mature plants should be applied during or just after flowering (see section III.4). Since chemical and mechanical treatment methods prescribed for poison ivy usually require more than one application, it is important that monitoring occur frequently enough after the first treatment to detect if and when a second treatment is needed.

This usually means that treated plants should be visited again a minimum of two-to-four weeks after initial control efforts. If a second treatment appears to be needed, another post-treatment monitoring visit should be scheduled. A final visit at the end of the growing season should be conducted to determine the overall effectiveness of the treatment program. Plants believed to be dead sometimes resume growth after many months; thus an area under treatment must be watched closely for at least a year to determine if retreatment is necessary (Crooks and Klingman 1967).

As a native plant, poison ivy tends to enjoy a stable relationship with the herbivores and pathogens that feed on it. Thus, suppression of its growth by native natural enemies is not likely to be significant.

2. Threshold/Action Population Levels:

Injury level refers to the point in the growth of the pest population when the numbers of pest organisms are sufficient to cause unacceptable structural, economic, aesthetic or medical damage (injury). When applying the injury level concept to weed problems, it is useful to substitute the phrase "tolerance" levels as a synonym for "injury" levels.
Several variables should be considered in establishing any weed tolerance level. These include:

a. species and growth habit;
b. location of weed problem;
c. weed population size;
d. type of actual or potential damage caused by weed;
e. degree of invasiveness of growth;
f. costs of managing the weed problem (including lost work time, responding to complaints, education of staff and visitors, etc.).

These variables may differ from site to site depending on the location, overall maintenance objectives, role or value of the plants in the environment, opinions and experience of managers, level of complaints by visitors or staff, etc. In the case of poison ivy, the adverse health effects that contact with the plant pose to humans usually render tolerance levels very low.

Similarly, the potential damage to buildings posed by poison ivy may also justify low tolerance levels. Like Boston Ivy (Parthenocissus tricuspidata) and English Ivy (Hedera helix) (Warnock et al. 1983), Poison Ivy attaches to stone masonry, wood and other building materials by means of aerial rootlets which are capable of penetrating and enlarging small cracks in the structure. This habit can result in water damage and general weakening of the building. The dense foliage and thicket of roots produced by poison ivy also can visually obscure the building surface so that damage goes undetected.

Tolerance for poison ivy growing on trees, however, may be high due to the fact that vines and roots apparently do not cause injury to trees except where growth may cover the supporting plant and exclude sunlight (Crooks 1967).

In summary, in areas of high use near buildings, within campgrounds, and on major trails, tolerance levels would be low since the likelihood of human contact or damage to buildings is high. In low use and remote areas of the park, tolerance levels for poison ivy could be quite high, since human contact is less likely. In general, poison ivy should only be controlled in developed sites where the plant is likely to come in contact with humans or damage structures.

3. Management Alternatives Non-Chemical

A. Indirect suppression: This approach attempts to change the conditions that create or define the pest problem. Examples are:

a) design or redesign of the landscape or the plant care system for the purpose of reducing or eliminating weed growth;

b) modifying the habitat in some major way to discourage growth of a particular weed species;

c) human behavior changes including the alteration of use patterns or maintenance practices contributing to weed growth, or education to increase tolerance levels for the "weed" species.

Poison ivy is primarily a problem in landscapes or areas that have been left to revert to a more "natural" state after previous human management. Redesigning the area is rarely a desirable strategy because of the basic objective of keeping the area as "natural" as possible.

However, in developed park areas designers of latrines, visitor centers, campgrounds, fencelines, etc. should be encouraged to avoid creating bare areas beneath likely bird perches as these conditions optimize the establishment of poison ivy.

No examples of using habitat modification to manage poison ivy could be found in the literature. However, ecological information on the pest suggests that application of deep mulches to bare soil could restrict germination of poison ivy seeds (See Section III.3

Where significant soil disturbance has occured it is important to seed in or plant fast-growing soil colonizing plants such as grasses or groundcovers in a effort to limit the soil space and nutrient reserve otherwise available to poison ivy. Although this tactic has not been documented specifically in the weed literature for poison ivy, it is a well-established weed control tactic for similar species (Daar, 1983b) and is worth testing on poison ivy.

To be most effective, the planting should occur as soon as possible after the soil disturbance has occured. Native plant species should be used whenever possible Consult local soil conservation and native plant organizations for recommended plant species.

In a park setting, it is important to educate visitors and staff on methods of identifying poison ivy so they can avoid contact with the plant. To the degree human contact with the plants can be avoided, treatments of the pest will be unnecessary. Signs, pamphlets and displays can be located at trailheads, campgrounds, visitor centers and similar areas where visitors are frequent.

B.Direct supression: This approach focuses on the pest and in the case of poison ivy several physical controls are available but biological controls are limited.

1. Physical controls:

a. Grubbing out

Seedling: Physical removal of poison ivy with digging and cutting tools is often the most effective means. Seedling plants can be dug out most easily in early spring after leaves have unfurled, but while the soil is still wet. By summer or fall of the first year, seedlings usually have a well-developed vertical and horizontal root system and are more difficult to remove.

Mature Plants: Late fall, after poison ivy has dropped its leaves and rains have saturated the soil, is usually the best time to dig out mature poison ivy. Since root systems may travel horizontally for 20 feet, extensive digging may be necessary. However, the roots do not appear to grow more than a foot or so deep, so extensive vertical digging is usually not required. After the initial grubbing has occured, treated areas should be monitored on a monthly basis to check for resprouts from rootstock inadvertently left in the soil.

In addition to shovels and mattocks, other tools useful when grubbing out poison ivy include brush hooks, McLeods (a double-edged digging tool), Pulaski's (a forester's axe), and gas-powered weedeaters with blade attachments. Hydraulic winches mounted on pick-up trucks are often useful in removing stems and roots of poison ivy growing in dense thickets.

b. Mowing

Seedling and young plants can be kept within an inch or two in height by frequent mowing (probably twice per month during the growing season). This regular removal of leaves and stems will restrict (but not eliminate) the development of horizontal roots. If a mowing program is adopted, it is important to collect clippings and dispose of them in a plastic bag or bury them to prevent the clippings from being spread over large areas and inadvertently contaminting park workers or visitors. If the plants are established clumps supported by mature rootstalks mowing should be done just before the plants bloom. Mowing is not recommended for poison ivy control in a lawn area used for picnicing or other recreational activities.

c. Cultivation

Poison ivy can be removed by repeated cultivation with a hoe, disk, spring-toothed harrow, or duck-foot cultivator. To be effective, cultivation has to occur frequently enough to remove new seedlings or young plants before they are able to form extensive perennial roots.

The actual cultivation frequency required is a function of several factors including extent of growth of poison ivy, soil conditions, type of adjacent vegetation, etc.

d. Girdling and Pruning

It may be possible to kill poison ivy by girdling stems or trunks. To do this, cut a band through the bark into the sapwood around the circumference of the stem. The incision cuts the sap transport vessels thus halting the movement of nutrients and water up and down the plant, causing eventual death.

Poison ivy growing as long vines on trees can be killed by severing their stems near the soil line with an axe or saw (Grant 1929). To minimize damage to the tree bark, the final cut should be made with a knife.

The severed vine can be pulled from the tree at the time the cut is made, or it can be left to dry on the tree over the summer and be removed in the fall when the dried leaves have dropped off and the remaining wood is less toxic to handle. After a month or six weeks, the new tops that spring from the inground portion of the stem may be pulled up (Grant 1929), injected or painted with an herbicide, or cut off repeatedly in hopes of starving the root system and achieving the eventual death of the plant.

e. Mulching

Once poison ivy has been removed from an area, it is desirable to cover the soil with a temporary groundcover to reduce the ability of poison ivy seedlings to recolonize the open ground. A deep mulch (6 - 12 inches) of hardwood chips is most likely to provide protection against poison ivy seedling emergence. Hardwood chips in the 1" x 2" size range are more effective than mulches made from bark. The smaller sizes of bark mulches and their easy decomposition by soil microbes limits their effectiveness.

NOTE: Never burn any part of the poison ivy plant. Tiny droplets of the oil will be carried on ashes in the smoke and can be breathed into the lungs. The throat may swell and the whole body can break out in an extreme rash. Whenever possible, dispose of poison ivy by burying. Plant pieces should be covered with at least 12" of soil to prevent sprouts from developing. If burying is not feasible, enclose plants in plastic bags for disposal in a landfill.

f. Biological control

A number of arthropods, micro-organisms and viruses are reported to feed on poison ivy (See Section 1.4). However, researchers are reluctant to pursue biocontrol programs on poison ivy because so little is understood about the beneficial roles played by this native plant The unknown risks to the environment caused by non-selective suppression of native plant species by biological control organisms could outweigh the benefits.

Suppression and even eradication of shrubby stands of poison ivy can be achieved by intensive grazing of livestock in areas where the plant is growing (Grant and Hansen 1929). Goats eat both foliage and stems of poison ivy. While few studies exist on using livestock specifically for poison ivy control, there is extensive experience with goats controlling similar brush species such as poison oak (Rhus diversiloba L.) in the western U.S., and useful extrapolations to poison ivy are probably in order (Daar 1983a; Green and Newell 1982).

Where appropriate, Angora, Spanish or other non-dairy goat breeds or sheep can be concentrated in an area containing poison ivy. A lightweight, portable, electrified plastic fencing called Flexinet® has been developed. It is powered by a 12 volt car battery or solar cell which generates sufficient current to keep livestock in and predators out. Fencing fabric is supported on non-conductive fiberglass fence posts. Flexinet® is available from the Waterford Corporation, Fort Collins, CO and in 1983 costs were approximately $100 for 150 feet .

The degree to which poison ivy is suppressed or eradicated by goats or sheep depends on a number of factors including herd size, duration of penning, state of succulence of vegetation, etc. Goats and sheep will graze or trample most of the vegetation in the area in which they are penned. Therefore, valuable vegetation such as specimen trees and shrubs should be protected by fencing or other barriers to keep the livestock at a distance.

4. Management Alternatives Chemical:

Since both shrub and vining forms of poison ivy usually grow in association with desired ornamental or native plant species, great care must be taken not to permanently damage such plants when using herbicides on poison ivy.

Typically, at least two herbicide applications are needed to kill all parts of the plant (Grant and Hansen 1929; Crooks and Klingman 1967). Seedlings should be treated in the spring as soon as new leaves are fully opened

(Daar 1983b). Translocated herbicides such as ammonium sulphamate (Ammate®) or glyphosate (Roundup®) should be applied on mature plants during or just after the bloom stage. This is the point when sugars are being translocated to the roots and will carry the herbicide throughout the plant system. If monitoring indicates retreatment is needed, a second application is best made as soon as resprouted leaves are fully expanded (Crooks and Klingman 1967). See Table 3 for a list of herbicides registered for use against poison ivy.

To keep damage to desirable plants to a minimum, use injection, frill or basal spray techniques where possible. Herbicide injection tools are available from forestry supply catalogues or other equipment sources. Frill methods consist of making shallow axe cuts around the circumference of the stem and applying herbicides into the cuts. Basal sprays involve coating the bark on the lower 12" to 24" of trunk or stem with herbicide.

When foliage sprays are required, spray nozzles which produce fairly large herbicide droplets should be used to limit drift of the herbicide. It may be useful to include an anti-drift product in the spray tank. Drift also can be minimized by using moderate pressure thus producing relatively large spray droplets, rather than high pressure which produces a driving mist (Crooks and Klingman, 1967).

Another application tool useful in confining herbicides to the target weed (spot-treatment) is a wick applicator. These tools absorb the herbicide on a rope, sponge or carpet wick and permit the applicator to wipe the herbicide directly onto the poison ivy. The applicators are made from common PVC plastic pipe and commercial rope, sponges or carpet pieces. They can be custom designed (or easily retrofitted) with long handles allowing the worker to stand some distance from the poison ivy yet still apply the herbicide. Manufactured, hand-held or machine-mounted wick applicators can be purchased from commercial sources.

The "jar method" is another technique of limiting drift. To implement this method, cut the tip off a trailing stem of the poison ivy plant. Discard the severed tip and place the cut end into a quart jar containing an herbicide solution for at least one hour. Jars (or other containers) should be stabilized so they don't tip over. It also may be necessary to use a wedge or fastener to hold the immersed shoot in position. The herbicide will be translocated throughout the plant's vascular system and the plant (or substan-tial portions) will die.

TABLE 3.

A COMPARISON OF EFFICACY, TOXICITY, MOBILITY & PERSISTENCE OF COMMON HERBICIDES USED AGAINST POISON IVY*

HERBICIDE	EFFICACY	TOXICITY (LD_{50})†	MOBILITY	PERSISTENCE SOIL/WATER††	COMMENTS
Ammonium Sulphamate (Ammate®)	H	L	L	S= 4-12 wks W= nd	Degrades to nitrogen and sulfur in soil
Aminotriazole (Amitrol-T®)	H	M	M	S= 7 weeks W= 201 days	Potentially carcinogenic in humans¶
Glyphosate (Roundup®)	H	L	L	S= >8 wks§ W= nd	
Sodium Chlorate (Chlorate/Borate mix is fire-retardant)	H	L	L-H	S= 12-52 wks W= nd	

*Herbicides from Herbicide Handbook. 1979. Weed Science Society of America.

†Ibid, Herbicide Handbook.

††Pimentel, D. 1971. Ecological Effects of Pesticides on Non-Target Species. Office of Science and Technology. USGPO. NOTE: This data is dependent on many variables including soil type, available moisture, rates of application, etc. Figures presented here should be considered approximations.

¶IARC monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans, Supplement I, 1979. IARC, Lyon, France, p. 22.

§Herbicide Handbook, op.cit., p. 226.

KEY:

Efficacy: H = High; M = Medium; L = Low

Toxicity: H = LD_{50}'s of 1-99 mg/kg; M = 100-1000; L = >1000.*

Mobility: H = High; M = Medium; L = Low

Persistence: S = soil; W = water; nd = no data

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The herbicides ammonium sulphamate, sodium chlorate or glyphosate can be used in the jar method. Use at the highest concentration permitted on the label.

Bates (1955) found that a 40 percent concentration of sodium chlorate was more effective at killing woody plants than were weaker solutions of 5 to 10 percent. Note that sodium chlorate is highly combustible and should be used with extreme caution.

The "jar" method works on the principle of negative root pressure and, according to Bates (1955), the best results are obtained in hot dry weather and at the height of summer. Treatment with the "jar" method in mid-winter and early spring seem to be the least effective and treatment of certain plants was without effect in late March, but rapidly effective in July. Once the plant is dead, the sodium chlorate, "does not appear to cause any injury when the weed decays. Whether this is due to the small amount present or whether it is due to the decomposition of the chemical, is not known (Bates, 1955). Ammonium sulphamate degrades to the fertilizers nitrogen and sulphur. If the "jar" method is used, workers must remain near the jars to insure that visitors, pets or wildlife do not come in contact with the poisons.

All pesticides are labelled for specific uses by the U. S. Environmental Protection Agency. All label instructions must be strictly followed.

5. Precautions for Handling Poison Ivy:

Poison ivy is toxic at all stages of growth--and even when dead from severed roots or herbicide spray (Crooks and Klingman 1967). Thus protective clothing should be worn no matter which treatment is selected. Workers should cover as much of the body as possible. Canvas or leather leggings over workpants provide extra protection when working in dense stands of the plants. Hands should be protected with thick canvas, rubber or leather gloves.

A beekeeper hat with veil can be used to protect the face when clearing dense stands of poison ivy. An industrial respirator mask should be worn when chopping or sawing plants to prevent breathing in sawdust particles, or when in the vicinity of burning poison ivy (burning is not a recommended method of control or disposal.)

Poison ivy sap can adhere to clothing, tools, and the coats of pets and livestock for very long periods of

time, and therefore serve as reservoirs for recontamination. For example, Shelmire (1941) reports that gloves stored at room temperature for 16 months still can cause poison ivy dermatitis. Thus it is important that clothing worn while working in or near poison ivy be carefully removed (use gloves), washed in hot, soapy water, and hung in the air to dry for several days in order to insure that all sap is deactivated (Gillis 1975). Repeated washing may be needed. Do not wash with other clothing. Using rubber gloves, clean tools after each use with a rag containing an oil solvent such as gasoline, alcohol, or turpentine. Rags and gloves should be enclosed in a plastic bag and discarded after use to prevent contamination.

Contaminated skin should be washed several times with water and a strong soap. The soap dissolves the oily sap and enables it to be removed from the skin. If soap is not available, cotton balls soaked in vinegar (2 tablespoons in 1 cup water) or alcohol (1/2 cup alcohol to 1/2 cup water) can be dabbed on the contaminated skin to dissolve the sap. Calamine lotion or a paste of baking soda can be topically applied to the dermatitis to relieve itching.

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NATIONAL PARK SERVICE
IPM Information Package

PRAIRIE DOGS

Final Report

15 April 1985

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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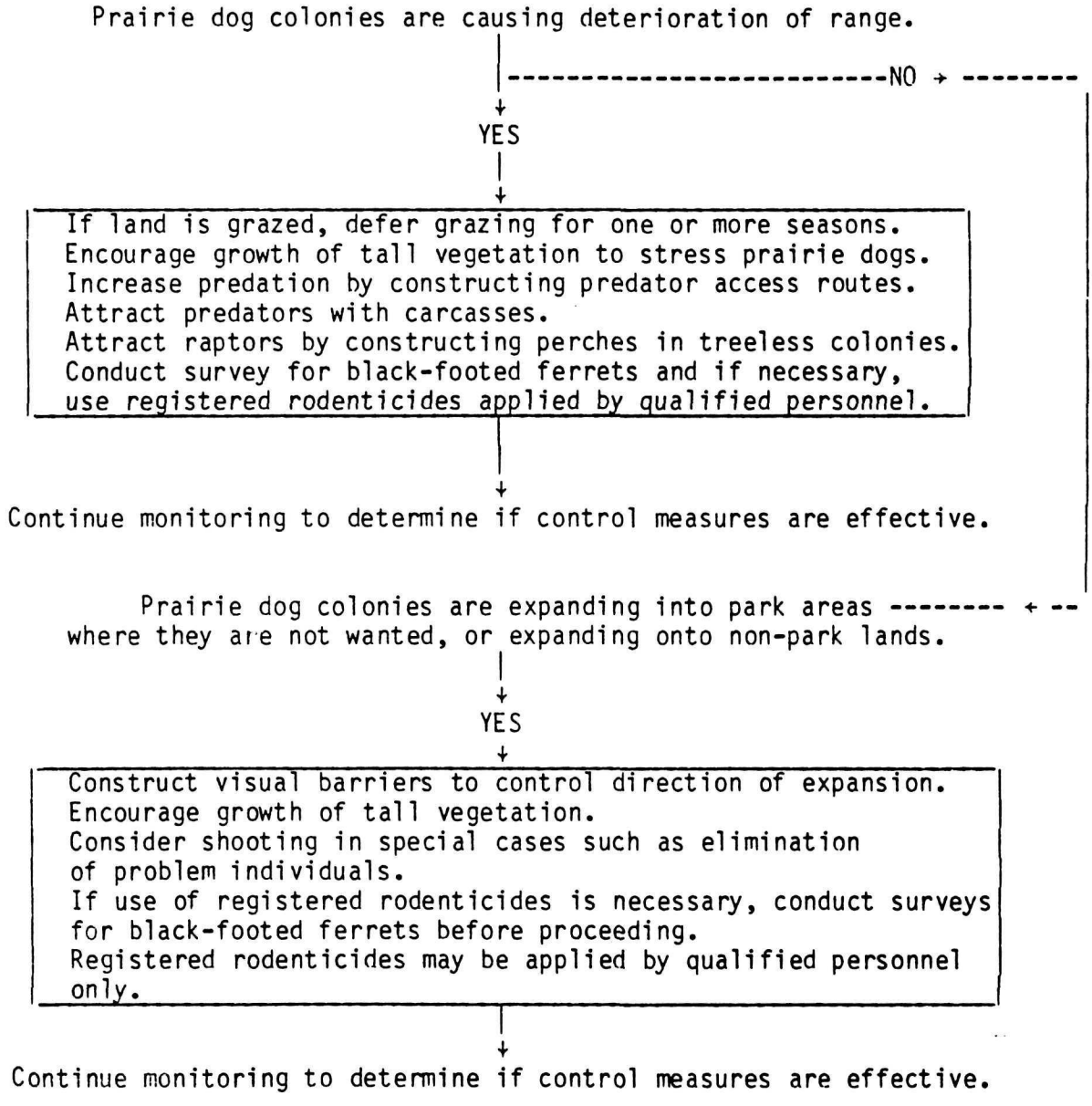
I. PRAIRIE DOG IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.

Monitor prairie dog populations and environmental conditions to determine if control is necessary.



II. PRAIRIE DOG BIOLOGY AND ECOLOGY

1. Species Described:

Prairie dogs are rodents in the family Sciuridae, which includes tree squirrels, ground squirrels, chipmunks, marmots, and woodchucks. All prairie dogs are in the genus Cynomys.

Prairie dogs have squat, somewhat stout bodies with short legs and long claws adapted for digging. The fur is coarse with black and buff colored tips. Color ranges from yellowish through sandy to cinnamon. The fur is often stained by the dirt in which they burrow. Belly fur is cream to white in color. The distal third of the tail is black in the blacktailed prairie dog, white in the other species.

The presence of prairie dog colonies is usually evidenced by bare earth mounds 25-75 feet apart. Each mound is approximately 1-2 feet high.

Prairie dogs can be divided into 2 groups, white-tailed and blacktailed. There are 4 generally recognized species of prairie dogs in the United States (the Mexican prairie dog C. mexicanus, does not occur in the U.S.), with several subspecies (Costello, 1970).

1. Blacktail prairie dog - Cynomys ludovicianus. Total body length (head and body) is approximately 11-13 inches. It is slightly smaller than a house cat in body size, but weighs much less (2-3 lb.). The tail is 3-4 inches in length, with a black tip. There are 8 mammae. This is the species most often considered pestiferous.

   a. Arizona prairie dog - C. l. arizonensis. Similar to the blacktail prairie dog, it is not usually considered pestiferous.

2. Whitetail prairie dog - C. leucurus. This and the next 3 species are similar. The head and body measure 11-12 inches in length. The tail is 1 1/4 - 2 1/2 inches long; the distal third is white. This species weighs 1 1/2 - 2 1/2 lb. There are 10 mammae. Whitetail prairie dogs are usually not considered pestiferous due to their comparatively low population densities.

3. Utah prairie dog - C. parvidens. Similar to the whitetail prairie dog, but with black spots above the eyes. The fur is uniformly brown or reddish. The distal half of the tail is white. This species is threatened.

4. Gunnison's prairie dog - C. gunnisoni gunnisoni. Similar to the whitetail prairie dog, but the distal half of the tail is white with a gray center.

   a. Zuni prairie dog - C. g. zuniensis. Similar to the Gunnison's prairie dog, but somewhat larger. The fur is pinkish cinnamon, with less buff in the belly fur.

Differences among these species are not apparent to most observers. Burt and Grossenheider (1964) include the whitetail, Gunnison's, Zuni, and Utah prairie dogs under one species, C. gunnisoni, which they refer to as the whitetail prairie dog.

See Burt and Grossenheider (1964) for color illustrations of blacktail and whitetail prairie dogs. See Costello (1970) for black and white photographs of all of the above species.

2. Geographic Distribution:

1. Blacktail prairie dog - Originally found on mixed to short grass prairie from Saskatchewan to west central Texas. The current distribution is from the Rockies to approximately 97°W longitude in central Oklahoma, Kansas, and Nebraska.

   a. Arizona prairie dog - Southeastern Arizona, south and central New Mexico, southwest Texas, and adjacent parts of Sonora and Chihuahua, Mexico. This species is now believed extinct in Arizona.

2. Whitetail prairie dog - Original range in mountainous parts of Montana, Wyoming, Utah, and Colorado, up to 12,500 feet. This species is now thought to be found only in Colorado and Utah.

3. Utah prairie dog - Restricted to Utah, recently found only in 9 counties. A threatened species.

4. Gunnison's prairie dog - Mountainous regions of central and south-central Colorado and New Mexico. Formerly abundant throughout its range, this species has been nearly extirpated by poisoning programs and sylvatic plague.

a. Zuni prairie dog - Formerly widely distributed in southeastern Utah, southwest Colorado, northwest and central New Mexico, and north central Arizona. This species is greatly reduced in numbers and range.

See Burt and Grossenheider (1964) and Boddicker (1983) for detailed range maps.

3. Habitat:

Prairie dogs are found in grassland or short shrubland habitats. They prefer areas of low vegetation with open vistas. In semiarid shortgrass, mixed, and midgrass rangelands, they seem to prefer to establish colonies near intermittent streams, buffalo wallows, temporary rain catch basins, water impoundments, old fields, homestead sites, windmills, old cemetaries, and similar situations. They do not tolerate tall vegetation well and avoid heavy brush and heavily timbered areas (Boddicker, 1983). Prairie dogs are sometimes found in tall grass prairie, but only in areas where heavy grazing by cattle, other livestock or wild ruminants keeps grasses short.

1. Blacktail prairie dogs - Dry upland prairies, shortgrass, or mixed grass prairie. Species in this group form colonies ("dogtowns") of up to several thousand (historically several million) individuals. Colonies may be up to several hundred acres in size.

2. Whitetail prairie dogs - Mountain valleys up to 12,500 feet in altitude, or desert, depending on species or subspecies. In open or slightly brushy country, with scattered woody plants. Usually found in isolated pairs, small families, or temporary family groups (clans); the species in this group are not as social as the blacktail prairie dogs.

4. Diet:

Prairie dogs feed primarily on grasses and forbs. Summers and Linder (1978) found buffalo grass, scarlet globemallow, threadleaf sedge, blue grama, and western wheatgrass to be the preferred food items. Other dietary components include six-weeks fescue, sand dropseed, foxtail, and various brome grasses. Prairie dogs eat seeds, succulent leaves, and stems as well as roots of plants. When grasses are scarce, they eat cactus, four-wing saltbush, rabbit brush, and bark from oak sprouts. They

also feed heavily on grasshoppers and other insects during summer months (Whitehead, 1927). Large prairie dog populations can graze significant amounts of forage from the range, causing vegetational changes which may persist for many years or decades, depending on such factors as soil type and climate.

5. Life Cycles:

1. Blacktail prairie dogs - Blacktails are diurnal, gregarious, and live in colonies (towns) of up to several thousand individuals. Population densities vary from 5 to over 50 prairie dogs per acre, with as many as 50 burrows per acre in varying degrees of use. Colonies are subdivided by topographical features into smaller assemblages known as wards which in turn are further divided into groups of related individuals (coteries) which defend home territories. Territories vary in size from .5 acres (Tileston and Lechleitner, 1966) to .7 acre (King, 1959). The coterie is the basic social unit, usually consisting of one or more adult males, several adult females, and associated offspring. Adult males are dominant within the coterie; when two or more males occur within the same coterie, one tends to dominate (Tileston and Lechleitner, 1966). All members of the coterie share food and burrows. Coterie members spend much time grooming and playing with each other. At least one animal in each coterie is on alert for predators while the others feed, play, or rest on top of the mounds. There is a highly developed communication system, with separate danger signals for terrestrial and aerial predators. Blacktail prairie dogs utilize at least 10 different sounds for various communications (Costello, 1970; Waring, 1970). Blacktail prairie dogs are not true hibernators but may become dormant in winter for periods of up to several days.

   Burrow systems range from very simple to extensive, with several chambers and escape tunnels. Separate chambers may be used as nurseries, latrines, resting areas, and air pockets in the event of flooding. Burrow systems vary in size, according to local soil conditions, depth of water tables, and the needs of individual prairie dogs. Burrows range from 15 to over 85 feet in length; depth varies from 3 feet to 10 feet (Sheets et al., 1971). Most tunnels have an entrance through a crater-shaped earthen mound, or a dome mound (a pile of earth beside the entrance hole) usually with a chamber a short distance inside, where the animal

can turn around. It is believed that burrow systems with both dome and crater entrances provide ventilation to chambers far below ground (Ferrara, 1985). Some burrow systems interconnect, and by plugging and unplugging tunnels and chambers, prairie dogs can modify systems to suit their current needs (Costello, 1970).

Mounds at entrances are built by pushing up soil from below and packing it firm. Blacktail prairie dogs use their forepaws and noses to pack earth. Mounds serve as lookout posts for predators and as dikes in the event of flooding.

Mating season for blacktail prairie dogs begins during early January in Kansas, and continues for the next 2-3 weeks. Further north, breeding may begin as late as early March. Most prairie dogs first breed at the age of 2 years, although some females may breed in their first year (Hoogland, 1982). After a gestation period of 28-32 days, 2-5 (rarely up to 8) young are born. Only one litter of young per year is produced. Young are born blind and hairless. Eyes open at 5 weeks, and by 6 weeks, the young venture above ground. Females do not allow adult males in or near nest burrows from the time they mate until the pups first appear aboveground. Females usually remain in a single coterie for life but young males tend to disperse from parental coteries from June to September, and adult males tend to move to other coteries before their female offspring mature (Hoogland, 1982). Blacktail prairie dogs live 4-5 years in the wild, and up to 8 years in captivity.

2. Whitetail prairie dogs - Life cycles are similar to those of the blacktail prairie dogs with some exceptions. Whitetails hibernate from October or November to March in high mountain valleys. The young of the year hibernate with adults in parental burrow systems. The mating season occurs from late March to mid-April, and young are born in early May. In deserts, whitetail prairie dogs may aestivate in July and August.

   Burrows are extensive, but mounds are seldom constructed. Whitetail and Gunnison's prairie dogs form piles of dirt around the burrow entrance. Zuni prairie dogs often form earthen ramps at the entrances to their burrows (Costello, 1970).

Due to the shorter season at higher elevations, whitetail prairie dogs spend less time above ground, and are not as colonial as blacktail prairie dogs; social interactions are not as well developed as among blacktail prairie dogs, due possibly to the more extensive vegetation which affords cover from predators, reducing the need for high levels of vigilance (Hoogland, 1981). Whitetail prairie dogs form clans (temporary family groups), usually dominated by adult females and consisting of mothers and their current litters occupying specific burrow systems. Well defined and defended boundaries do not exist between clans as is the case with coteries. Members of the same clan feed together and members of different clans normally interact with little conflict. Whitetail prairie dogs occupy larger areas and have much lower population densities than do blacktails.

Whitetail prairie dogs disperse in much the same manner as do blacktails, but do so over a wider area, resulting in much lower population densities.

Gunnison's prairie dogs usually occur singly, in pairs, or in widely separated family groups.

6. Seasonal Abundance:

Prairie dogs, like most small mammals, are most abundant after the young have been born in February and March, and before they disperse from the burrows, beginning in June.

Populations are lowest at the beginning of the breeding season, at about 2.5 per acre for blacktail and 1.4 per acre for whitetail prairie dogs. Maximum population densities are quite variable and are strongly influenced by local environmental factors (Campbell and Clark, 1981). Tileston and Lechleitner (1966) report maximum densities of approximately 13 blacktail or 3.5 whitetail prairie dogs per acre, but colonies with nearly 30 blacktail prairie dogs per acre have been reported (Alexander, in litt.). Whitetail prairie dogs have been reported at densities of 20 per acre (Alexander, in litt.).

7. Responses to Environmental Factors:

Exceptionally dry years, in conjunction with heavy grazing by wildlife or cattle, enchance prairie dog colony expansion. Wet years with abundant vegetation growth produce the opposite effect (Boddicker, 1983). Prairie dogs are most abundant in areas intensively grazed by livestock or wild ruminants which keep plants clipped to low heights (Uresk et al., 1981). Low vegetation allows prairie dogs to see predators and communicate visually with each other. In areas where vegetation is allowed to grow tall, blacktail colonies tend to decline. Vegetation height has little effect on whitetail prairie dog colonies (Hoogland, 1981). Dispersal of young in June to September serves to expand existing colonies, establish new colonies, or reestablish old, abandoned, or poisoned colonies in suitable habitat (Garrett and Franklin, 1981). Movement of breeding blacktail prairie dog males to different coteries helps to prevent inbreeding (Hoogland, 1982).

Colonies tend to expand outward after available vegetation in the central areas has been replaced by unpalatable plants (mostly forbs) which are not grazed by prairie dogs (Fagerstone, 1981). Immigration and emmigration have little impact on the overall dynamics of blacktail prairie dogs, but may be important for whitetails (Tileston and Lechleitner, 1966).

8. Impact of Prairie Dogs:

8.1 Direct Impact:

Blacktail prairie dogs cut vegetation from around their burrows for food, for nest lining material, and for removal of possible cover for predators, as well as to keep open lines of sight for communication and to scout for predators. Prairie dogs feed on the same forage as cattle and native ruminants, competing directly with them. The amount of aboveground forage eaten or made unavailable to livestock and other wildlife due to prairie dogs and other dogtown inhabitants is about 24% of the total potential annual production (Hansen and Gold, 1977). Whitetail prairie dogs generally do not cut vegetation for other than food uses (Tileston and Lechleitner, 1966).

Burrowing and the resultant bare earth around burrow entrances in colonies (resulting from subsoil being brought to the surface), may cause rough pasture surfaces and slow grass regeneration (Boddicker, 1983).

High-density colonies often overgraze forage to the point of reducing food sources for other wildlife. When the flora of an area has been changed by the action of prairie dog colonies, the fauna also changes. Declines in numbers of sharp-tailed grouse, pheasants, quail, and other game birds have been noted in the vicinity of colonies. Use of areas by mule deer and white-tailed deer may also be decreased.

Cottontail rabbit and jackrabbit populations may increase due in part to increased forb populations. Black-footed ferrets depend on prairie dogs as their sole source of food and shelter (ferrets nest in abandoned burrows). Burrowing owls and prairie rattlesnakes are also often found in prairie dog colonies, living in abandoned burrow systems. Pronghorn antelope thrive on range where prairie dog colonies occur, feeding on forbs which grow in place of grasses (Boddicker, 1983). Short-term prairie dog impact enhances grazing for bison by increasing forage nitrogen concentration and forage accessibility (Layne, 1980). Prairie chickens and sharp-tailed grouse may utilize colonies for leks (mating display areas) during breeding season. Mice, ground squirrels, toads, tiger salamanders, and ornate box turtles, as well as many insect species, may utilize burrows for temporary or permanent shelter.

8.2 Indirect Impact:

Prairie dogs are susceptible to and may harbor the ectoparasites which transmit sylvatic plague. Prairie dogs are the most frequently cited "reservoirs" for sylvatic plague in the western U.S. (Hansen and Gold, 1977).

9. Natural Enemies:

Prairie dogs are preyed upon by a wide variety of predators including the following: coyotes; bobcats; swift, kit, red, and gray foxes; badgers; longtailed weasels; prairie rattlesnakes; bull snakes; golden eagles; ferruginous hawks; rough-legged hawks, and other large raptors; and the endangered black-footed ferret. Badgers are the principal predator of both whitetail and black-tail prairie dogs (Tileston and Lechleitner, 1966).

Predators are believed to have minimal impacts on prairie dog populations (Campbell and Clark, 1981).

Female prairie dogs have been observed to kill the litters of other (related) females in the same

coterie. Presumably this behavior is related to crowding and associated stresses, but has not yet been investigated fully (Ferrara, 1985).

Diseases such as sylvatic plague and tularemia may sweep through overcrowded colonies, killing many of the residents, and causing colony decline due to associated social stresses, as well as leading to increased predation caused by fewer animals acting as sentinels.

III. PRAIRIE DOG MANAGEMENT

1. Population Monitoring Techniques:

The endangered black-footed ferret occurs with and depends upon prairie dogs for food and shelter. Any control program for prairie dogs should recognize the possibility of the existence of black-footed ferrets in the area. Pre-control surveys for black-footed ferrets should be conducted. Contact the U.S. Fish and Wildlife Service, Pierre, S.D., for assistance and information (see Page 15 for addresses and phone numbers).

Color infrared aerial photography at 4000 feet (1370 m) above ground has been used to delineate active prairie dog towns and possible expansion directions. Changes in vegetation common in and around prairie dog towns are used as key indicators which appear as different colors on aerial photographs (Dalsted et al., 1981). Color infrared (CIR) is superior to black and white films because CIR can detect towns less than 4 ha (9.5 acres) in size, a detail not possible with most black and white films.

Observation of colonies using binoculars from a blind is an excellent method of monitoring for activity and to obtain population estimates. See Hoogland (1981; 1982) for interpretations of various behaviors.

Mapping dogtowns, using standard surveying equipment, is an accurate (although expensive in terms of manpower and time) method of surveying the extent of prairie dog towns. It should be kept in mind that not all burrows are occupied at the same time. A rough estimate of numbers can be made by carefully examining burrow entrances for fresh dirt, feces, or signs of dirt packing, and assuming 1 animal per active entrance (Costello, 1970).

Records and detailed maps should be kept to chart the growth or recession of colonies over time.

2. Threshold/ Action Population Levels:

Prairie dogs are native animals and in most cases should be left unmolested. In some instances, control may be necessary to prevent colony expansion into areas where the presence of prairie dogs is not desired, where other park resources are threatened, or where diseases such as sylvatic plague may be transmitted.

Contact NPS health and safety officer if sylvatic plague is suspected in your area.

3. Management Alternatives-Nonchemical:

Prairie dogs are usually a problem in areas where the range has been chronically overgrazed by livestock or wildlife.

A nonchemical management program would ideally consist of habitat changes which increase vegetative growth allowing greater predator access, changes in food sources, and resultant social stresses to reduce prairie dog densities to the point where they are no longer pestiferous (Garrett and Franklin, 1981).

Consider resting overgrazed pasture or range by excluding livestock or wildlife for at least 1 season. Snell and Hlavachick (1980) deferred grazing in selected plots in June, July, and August to allow vegetation to recover, followed by spring grazing at double the normal grazing pressure to compete with prairie dogs for early cool-season vegetation. In an area where pastures were managed for 4 successive growing seasons, the prairie dog colony under study was reduced from 110 acres to 12, and grasses reestablished. The authors emphasized that this was not a scientific experiment, but a series of trials and observations.

Increased predation in the area was attempted by placing hay bales in general lines 15-20 feet apart from the edge of draws and other existing cover to the center of prairie dog colonies. No significant difference in predation, however, was noted between the study area and nearby bale-free areas (Snell and Hlavachick, 1980). Further attempts were made to attract predators into the area by placing carcasses of cattle or other livestock, which had died during the winter, in the middle of a colony, although it is not known if predation on prairie dogs was increased. Snell and Hlavachick further suggest that predation by birds may be enhanced by placing raptor perches in the form of dead trees around otherwise treeless colonies. Perches may serve to increase predation, and to stress prairie dogs by the increased presence of raptors, although supporting data are lacking.

Colony expansion may be curtailed or changed in direction by the use of visual barriers. Garrett and Franklin (1981) report that barriers constructed of rows of burlap affixed to steel stakes positioned 30 feet (10 m) apart served to significantly reduce

colony expansion compared to areas with no barriers. Barriers may also serve to increase predation by providing increased cover to predators.

Shooting, although historically used to control prairie dogs, is not recommended for general use due to possible safety hazards and overall lack of effectiveness. Shooting tends to make prairie dogs wary of human presence, but does not significantly reduce numbers. Shooting to eliminate individual prairie dogs in special circumstances, and when used in conjunction with other control techniques, may be a viable control measure.

Traps have been used to capture individual prairie dogs causing damage in small areas. Box traps, snares, and #110 Conibear® or equivalent traps have been used with success (Boddicker, 1983). Steel leghold traps are not recommended for humane reasons.

4. Management Alternatives-Chemical:

Diethylstilbestrol (DES), a synthetic estrogen compound, has been found to inhibit reproduction in prairie dogs under experimental conditions (Garrett and Franklin, 1981). Because prairie dogs produce only one litter per year, and females within a colony come into estrus at approximately the same time, management efforts were minimal and did not interfere with other wildlife species. Reproductive inhibitors are expensive, and may be prohibitively so on low value areas such as rangelands, but in some circumstances (such as preventing colony growth onto private lands), may be useful control measures. They must be reapplied each year to inhibit reproduction. Potential effects of DES or other reproductive inhibitors on the food chain have not been quantified. DES is experimental only and is not registered by the EPA. It is not currently recommended for NPS use.

The use of most lethal chemicals on prairie dogs are restricted (with the exception of gas cartridges); permits are required. Zinc phosphide and gas cartridges have been recommended for prairie dog control in the past. Lethal baits for prairie dog control should be used by qualified personnel only. Surveys to determine the presence of black-footed ferrets should be conducted prior to treatment. Contact the U.S. Fish and Wildlife Service for assistance and guidelines in conducting ferret surveys. Henderson (1983) details the proceedure and gives the names and addresses of contact personnel.

Rodenticides are mixed with oats and usually follow a prebait application of non-treated oats. Mortality following rodenticide treatments is generally in excess of 90%. Retreatments are usually required within 3 years due to immigration from untreated areas.

Other methods such as automobile exhaust, dry ice, and gasoline fumes have been used to kill prairie dogs in their burrows. These techniques are not recommended due to lack of effectiveness or danger involved.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Determine the nature of the prairie dog problem. If prairie dogs are in a natural area, no action is recommended.

2. Conduct surveys using aerial photography, mapping, observation, or hole counting methods to estimate populations and densities.

3. Consider habitat modification by deferred grazing or use of visual barriers to control or direct colony growth and expansion. Records should be kept concerning the outcome of such attempts.

4. If necessary, use zinc phosphide or gas cartridges, to reduce prairie dog populations to tolerable levels. Rodenticides may be used in combination with trapping and/or shooting. If rodenticide use is planned, contact:

    U.S. Fish and Wildlife Service
    P.O. Box 250
    Pierre, South Dakota 57501
    (605) 224-8692
    FTS: 782-5226

    for information and assistance in conducting surveys for prairie dog with respect to black-footed ferret populations.

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NATIONAL PARK SERVICE
IPM Information Package

RATS

Final Report

27 July 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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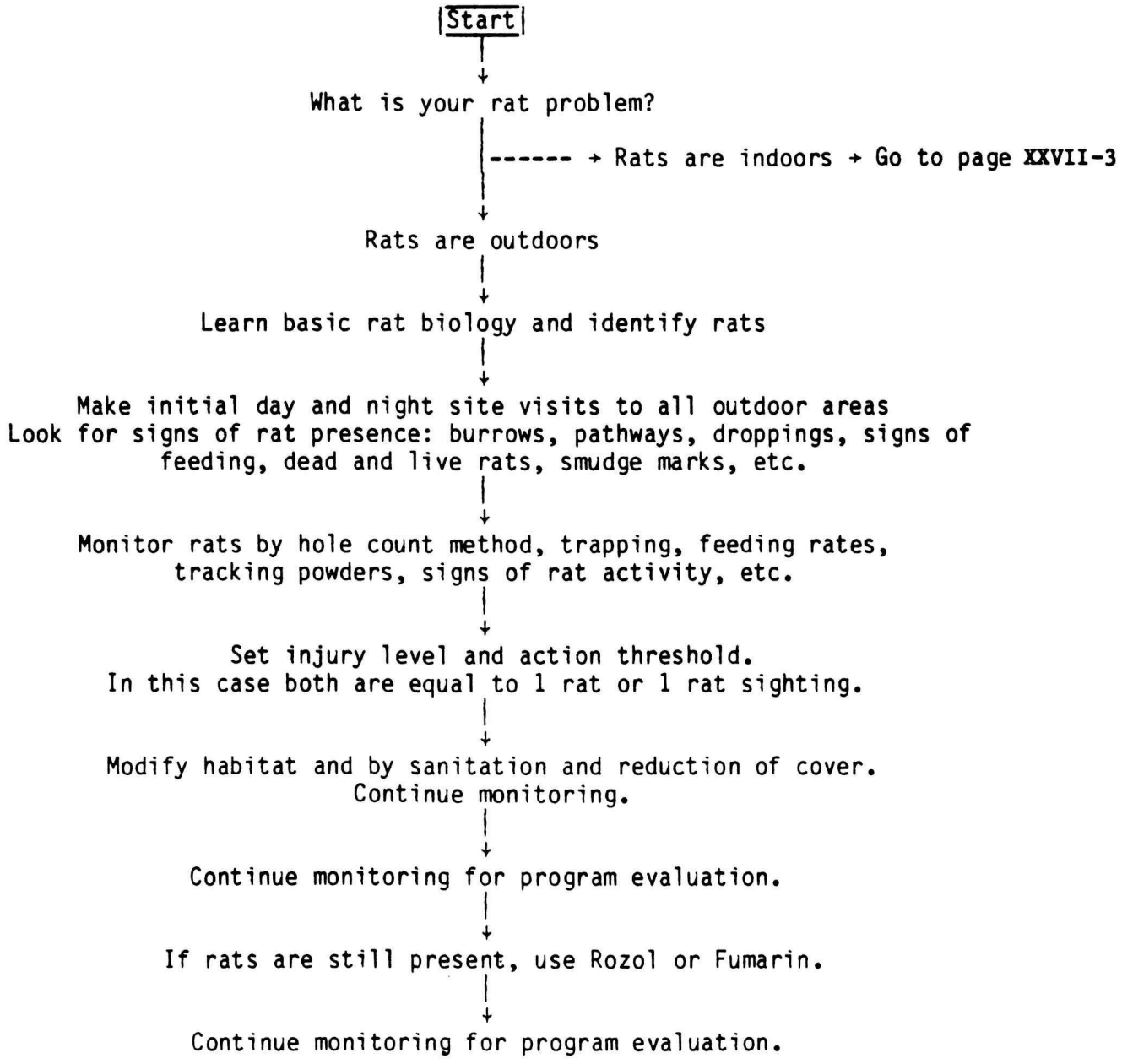
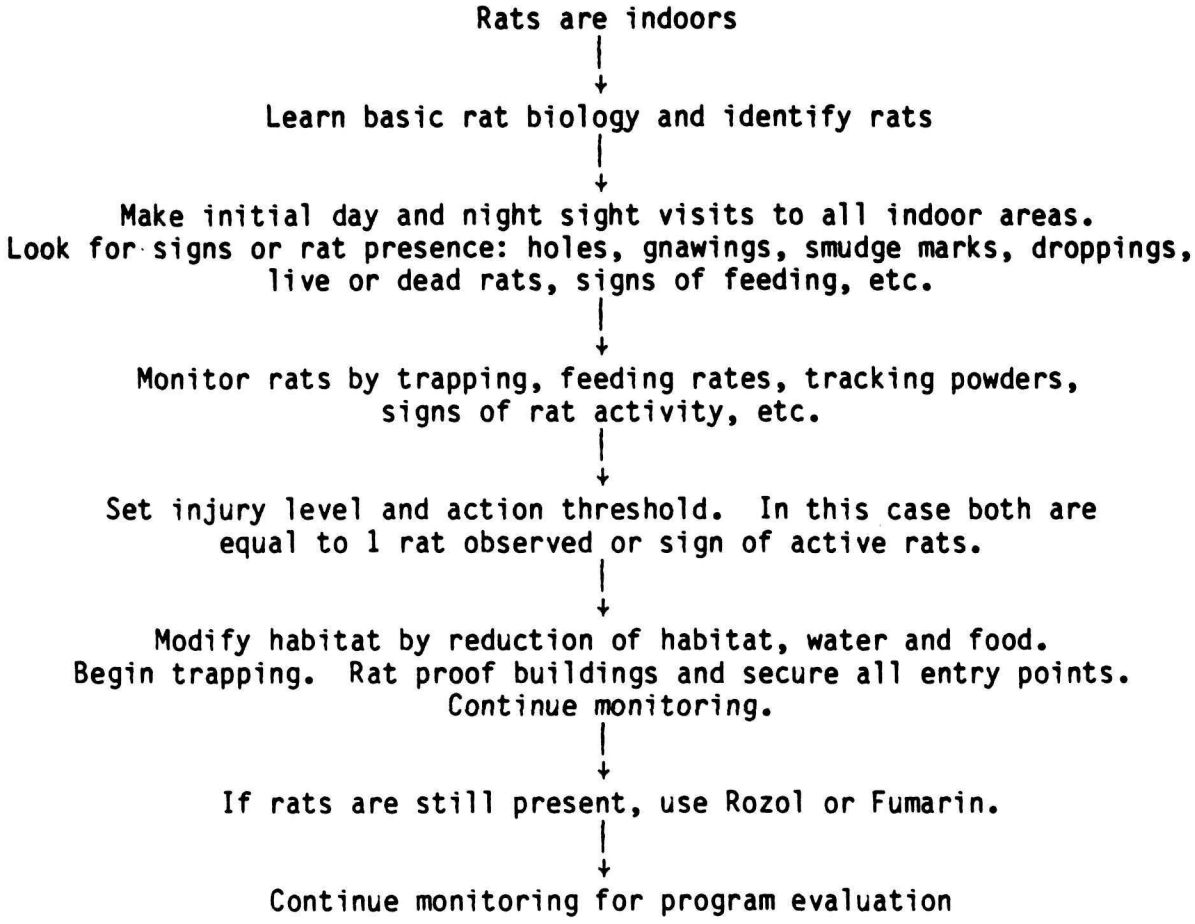
I. RAT IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




Rats are indoors
Learn basic rat biology and identify rats
Make initial day and night sight visits to all indoor areas. Look for signs or rat presence: holes, gnawings, smudge marks, droppings, live or dead rats, signs of feeding, etc.
Monitor rats by trapping, feeding rates, tracking powders, signs of rat activity, etc.
Set injury level and action threshold. In this case both are equal to 1 rat observed or sign of active rats.
Modify habitat by reduction of habitat, water and food. Begin trapping. Rat proof buildings and secure all entry points. Continue monitoring.
If rats are still present, use Rozol or Fumarin.
Continue monitoring for program evaluation

II. RAT BIOLOGY AND ECOLOGY

1. Species Described:

   A. Norway rat - *Rattus norvegicus* Berkenhout

   B. Roof rat - *Rattus rattus* L.

   See pages 181-183, U.S. Department of Health, Education, and Welfare (1967) for a comparative key to rodent species.

2. Geographic Distribution:

   See Howard & March (1974) for a detailed distribution map of rats of U.S.

   A. Norway Rat - World-wide, including North America to southern Alaska and Hawaii. May be scarce in uninhabited areas of the Western U.S.

   B. Roof Rat - World wide including coastal portions of California, Oregon, Washington, and most of the southern U.S. from Maryland to Texas.

3. Habitat:

   A. Norway Rat - Closely associated with human habitation, may move to fields in warm months to feed on crops, but returns to buildings with advance of cold weather. May live independently of man in marshes. Outdoors, constructs burrows in ground; indoors, prefers lower floors, basements.

   B. Roof Rat - Seems to be less dependent on man than Norway rats. May live in forests far from human habitation, especially in warm areas. See Pratt & Brown (1977) for detailed information on rat habitat. Arboreal outdoors; indoors prefer upper floors and attics.

   NOTE: In areas of high population densities, Norway rats may live in trees and roof rats may burrow.

4. Hosts:

   Pest rats generally live in close association with humans, feeding on stored or waste food and nesting in structures or outdoor urban areas.

5. Life Cycle:

   A. Norway Rat - Breeds at any time during the year, but more frequently in warm months. Gestation lasts 22-24 days. Size of litter is usually 8-10 pups. A female may breed at 2-5 months of age and have an average of 3-4 litters per year. Adults weigh 10-17 oz. Life span generally 9-24 months.

B. Roof Rat - May breed throughout the year, but more commonly in warm months. Gestation lasts 20-22 days. Size of litter usually 4-8 pups. A female may breed at 2-5 months of age and have an average of 5.4 litters per year. Adults weigh 4-12 ounces. Life-span is 9-12 months.

6. Seasonal Abundance:

Outdoor rat populations tend to peak in summer-early fall. They tend to be at their lowest levels in late winter-early spring, due to winter-associated mortalities. Indoors, rat populations may remain at the same levels throughout the year, limited only by shortage of food.

7. Responses to Environmental Factors:

Rat abundance is dependent on availability of food, water and shelter. When Norway and roof rats are found together, Norway rats will outcompete roof rats in most cases. Over-crowding may lead to increased aggressive behavior and lower birth rate in Norway rats. Increased emigration related to overcrowding is common in both species.

8. Medical Importance:

Rats have always been of medical importance due to their transmission of human diseases.

8.1 Direct Effects:

Rat bites, particularly in urban areas, may be a serious health problem. An estimated 14,000-24,000 bites to humans occur each year. Infants and helpless adults (unconscious, invalid, and elderly) are subject to attack by rats, sometimes fatally. All rat bites should receive medical attention.

Rats spread a number of human diseases directly through contamination of food and water with urine and feces.

8.2 Indirect Effects:

Rats may indirectly spread a number of human diseases by way of fleas and mites. Some of the more common diseases spread by rats include plague, rat-bite fever, Weils disease (leptospirosis), murine (scrub) typhus fever, ricketsialpox, trichinosis, salmonellosis, listerosis, toxoplasmosis, and lymphocytic choriomeningitis (see Pratt et al.(1976) for more complete treatment of rat-borne diseases).

8.3 Outbreaks of Rat Associated Diseases: Many of the diseases listed in Section 8.2 can be fatal to humans. If disease transmission is suspected in your area, contact your NPS Public Health Service representative, and collaborate with him on any measures needed to deal with outbreaks.

9. Natural Enemies:

A. Rats may be preyed upon by many other animals including dogs, cats, weasels, snakes and owls. Rats are susceptible to a variety of diseases and parasites. Some natural enemies ranging from ferrets to bacterial toxins have been used in the past with varying degrees of success in rat control programs.

B. In abnormally crowded conditions or other stress situations, rats may display aggressive behavior toward each other, including cannibalism and abandonment of young.

III. RAT MANAGEMENT

1. Population Monitoring Techniques:

A. Norway rat - Periodic surveys of buildings and grounds can reveal the existence of rat infestation. Although several techniques are effective for detecting rat presence (see below), a careful search for signs of rats should be conducted as well. Monitoring visits should be made every other week and increased or decreased according to the severity of the problem.

1. Signs of Rat Presence:

Sounds, droppings, burrows, urine stains, smudge marks, runs, tracks, gnawings, nests, food caches, pet excitement and rat odors are all signs of rat activity. Learn to differentiate between fresh rat sign and old sign which may indicate old (non-active) infestations (see Pratt & Brown (1977) for detailed descriptions).

a. Rat sign may be interpreted as follows:

Rat free area or low rat population:
no signs of rat presence; invaded only recently, or habitat will support few rats.

Medium population:
old droppings and gnawings common, one or more rats seen by flashlight at night, none during the day. Each rat seen at night usually indicates 10 or more elsewhere.

High population:
fresh droppings, tracks and gnawings evident, 4 or more rats seen at night or 1 or more in daylight.

b. Rat entry points (in structures) and travel routes (in structures and outside); see Howard & Marsh (1974). Adult rats can gain entrance through any opening larger than 3/4 inch square. Young rats (and adult mice) can gain entrance through openings as small as 1/2 inch square. Ill-fitting door jambs and window frames are common points of rat access.

Entry points, if frequently used, may have smudge marks from dirt and oil in the fur, or may be clean of dust. Travel routes are frequently found along walls due to

rats' preference for keeping in contact with vertical surfaces (thigmotropism). Travel routes indoors are free from dust, and may have droppings and urine stains. (Rat urine will flouresce under ultraviolet light.) A 6" white band along the wall may be usefull in detecting rat presence in structures.

Travel routes outdoors can be detected by the lack of grass or presence of worn areas radiating to or from a single area.

2. Tracking powders, such as chalk or talc, may be used in likely runs in undisturbed indoor areas. A small amount is spread thinly on a area 6" x 18" and examined at regular intervals for tracks. Relative abundance of tracks is an indication of rat abundance.

3. Feeding rates - Estimates of the minimum number of rats present can be determined by placing premeasured, ground, nontoxic cereal bait in various locations to determined how much is eaten each night. Double the amount each night until the amount taken in one night levels off. Divide the amount by 1/2 oz. This will provide an estimate of the minimum number of rats (see Howard & March (1976) for detailed instructions).

4. Trapping - Estimates of numbers or approximate levels of infestation can sometimes be obtained by trapping. This method is not often used because remaining rats become trap shy and difficult to control. Trapping is normally used as a control measure.

5. Hole counts (outside) - Estimates of relative abundance can be made by counting, mapping, and loosely plugging burrow entrances on a weekly basis. Burrows which are open the following week are active. See Giraldi & Hackett (1982) for details.

B. Roof Rat - See 1.A. (Norway rat)

2. <u>Threshold/ Action Population Level:</u>

A. Norway Rat - In most circumstances the injury (threshold) level is one rat as determined by rat sighting or sign. The action level is one rat for population reduction programs and 0 rats for preventative programs.

B. Roof Rat - See 2.A. (Norway Rat)

3. Management Alternatives - Non-chemical:

A. Norway Rat

1. Habitat modification, i.e., reducing the capacity of the environment to support rats, is the most effective long term population reduction technique.

   a. Reducing food - In urban settings rats feed largely on garbage. Regular trash pickups at the end of each day, rather than storing trash overnight and the use of rat proof trash containers are relatively simple methods of reducing rat food sources. Food handling and food storage facilities should be made rodent proof (see below). Pet food dishes and water dishes should not be left full overnight. See Giraldi & Hackett (1982) for suggestions on rodent proofing trash containers and storage facilities (such as galvanized metal disks to prevent rats from gnawing into the bottoms of plastic trash containers).

   b. Reducing water - This technique is impractical in all but a few situations. If other water sources are unavailable, leaky faucets and seeps should be repaired.

   c. Reducing harborage - Outdoors: Landscaping should not include thick hedges or bushes which obscure the ground. Ground covers and walls should not include plants such as ivy which provide cover or runs for rats. Indoors: Buildings should be rat proofed with metal kick plates on doors, metal jambs on windows and doors, and cracks and holes in outside walls should be repaired. (see Scott & Borom (1976) for methods and techniques), L-shaped footers or curtain walls should installed where needed. Cement used in patching holes should be mixed with broken glass to prevent rats from digging it out before it sets and hardens.

2. Trapping - Trapping (along with baiting) is used where rapid population reduction is needed. Habitat modification should always accompany trapping or baiting to prevent future infestations. Traps are used in situations where use of poisons would be dangerous, to eliminate bait shy or bait resistant rats, to avoid odors from dead rats

in unaccessible places, or to collect live rats for ectoparasite or anticoagulant resistance screening. Snap traps are commonly used. Steel traps are considered dangerous and inhumane and should be avoided if possible. Glue boards are often used for mouse control, but can also be used against rats. (See CDC Publication #119 for information on trapping).

B. Roof Rat - See 3.A. Norway rat; in addition, all cables trees and pipes leading to or touching structures should be rat proofed with galvanized metal barriers to exclude this arboreal species if it is present. See Scott & Borom (1976), for details on indoor ratproofing. Giraldi and Hackett (1982) also give details on ratproofing in structures.

4. Management Alternatives - Chemical

A. Norway Rats - Rodenticides are commonly used to provide rapid reduction of rat populations. Rodenticides should be used in conjunction with habitat reduction to avoid chronic reinfestation.

1. Single dose (acute) rodenticides - These are fast acting poisons which kill rats after a single feeding. These chemicals should be applied by experienced professionals, as most are extremely hazardous. Examples of acute rodenticides include: red squill, strychnine, and ANTU.

Vacor and norbromide were once commonly used but are no longer registered for use in the United States.

2. Anticoagulants - These act only after the rat has consumed several doses. They act by disrupting the normal blood coagulation process, causing fatal hemorrhaging. They have the advantage over acute poisons in that they are safer to nontarget animals, and rats do not associate them with illness and learn to aviod them (as is the case with some single dose rodenticides). Some examples of anticoagulants include: warfarin, fumarin, difenacoum, tomorin, coumatetralyl, pical, diphacinone, chlorophacinone (Rozol®), and PMP. Broadifacoum (Talon®) is a second generation anticoagulant used as a single dose poison.

Resistance to some anticoagulants, especially to warfarin, has been noted in several U.S. cities.

3. Gassing - Several gasses are available for burrow and/or structure fumigation. Fumigants commonly used include: calcium cyanide, methyl bromide, carbon bisulfide, carbon dioxide, and phostoxin. These compounds are extremely hazardous and should only be used by experienced professionals.

B. Roof Rats - See 4.A.

5. Summary of Management Reccomendations:

1. Outdoors, reduce carrying capacity of habitat by reduction of cover (removal of thick shrubbery, rubbish piles, lumber stored on the ground, etc.)

2. Reduce availability of food by modifications to waste cans and dumpsters (repairing holes, use of galvanized metal plates to prevent rats from gnawing their way in, etc.). Do not store garbage overnight. Frequent pick-up and disposal will reduce rat food sources.

3. Indoors, repair all cracks and holes which may serve as entry points (rats can pass through any opening greater than 1/2" square). Structures should be rat proofed with galvanized metal shields over all entry points (door jambs, window frames, electrical wires leading to the structure, etc.). Branches touching the roof should be cut back. Use of L-shaped curtain walls will prevent rats from burrowing into structures.

4. If necessary, begin a trapping program in areas where humans or pets will not be injured. Use snap traps or glue boards if possible. Live traps may be used in special circumstances. Traps should be placed in areas of frequent rat usage (runways, where smudge marks appear, etc.).

5. If necessary, begin treatment with chlorophacinone (Rozol) or Fumarin in areas of known rat presence. Monitor frequently to make sure bait is accepted. Dispose of carcasses and uneaten baits.

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V. SAMPLE RAT MONITORING FORM

DATE:_____ PLACE:_____ INVESTIGATOR:_____

OBSERVATIONS: (Note location if observed)

Droppings:	Runs:	Tracks:
Smudge Marks:	Gnawings:	Nests and Food Caches:
Urine Stains:	Holes:	Other:

STRUCTURAL DEFECTS: (Note location if observed)
Holes or cracks 1/2" or greater around pipes or wires:
Open vents or chutes:
Unscreened roof vents:
Wires (electrical or telephone) going to upper floors:
Other:

LANDSCAPE FLAWS: (Note location if observed)

Is heavy shrubbery or vine foliage providing possible cover?	Y	N
Is ground visible under shrubbery or flower beds to permit monitoring?	Y	N
Is lumber, fire wood, etc. stored on the ground?	Y	N

Other:

SANITATION:
How often is refuse collected?
Is refuse stored in the park buildings overnight?
Is material stored inside off the ground and away from walls?
Are refuse receptacles rodent proof?
Are there food concessions in the area?
Other:

Sketch in map or floor plan of area monitored. Show all items noted above.

Additional Notes:

NATIONAL PARK SERVICE
IPM Information Package

SCALE INSECTS

Final Report

15 April 1984

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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I. SCALE INSECT IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.

What is your scale problem?

You wish to prevent scale infestations.

↓ Yes

Promote plant vigor and conserve populations of natural enemies by careful timing of pesticide treatments, and by providing alternate food sources (ie.; nectar bearing plants) to attract and maintain natural enemy populations.

No →

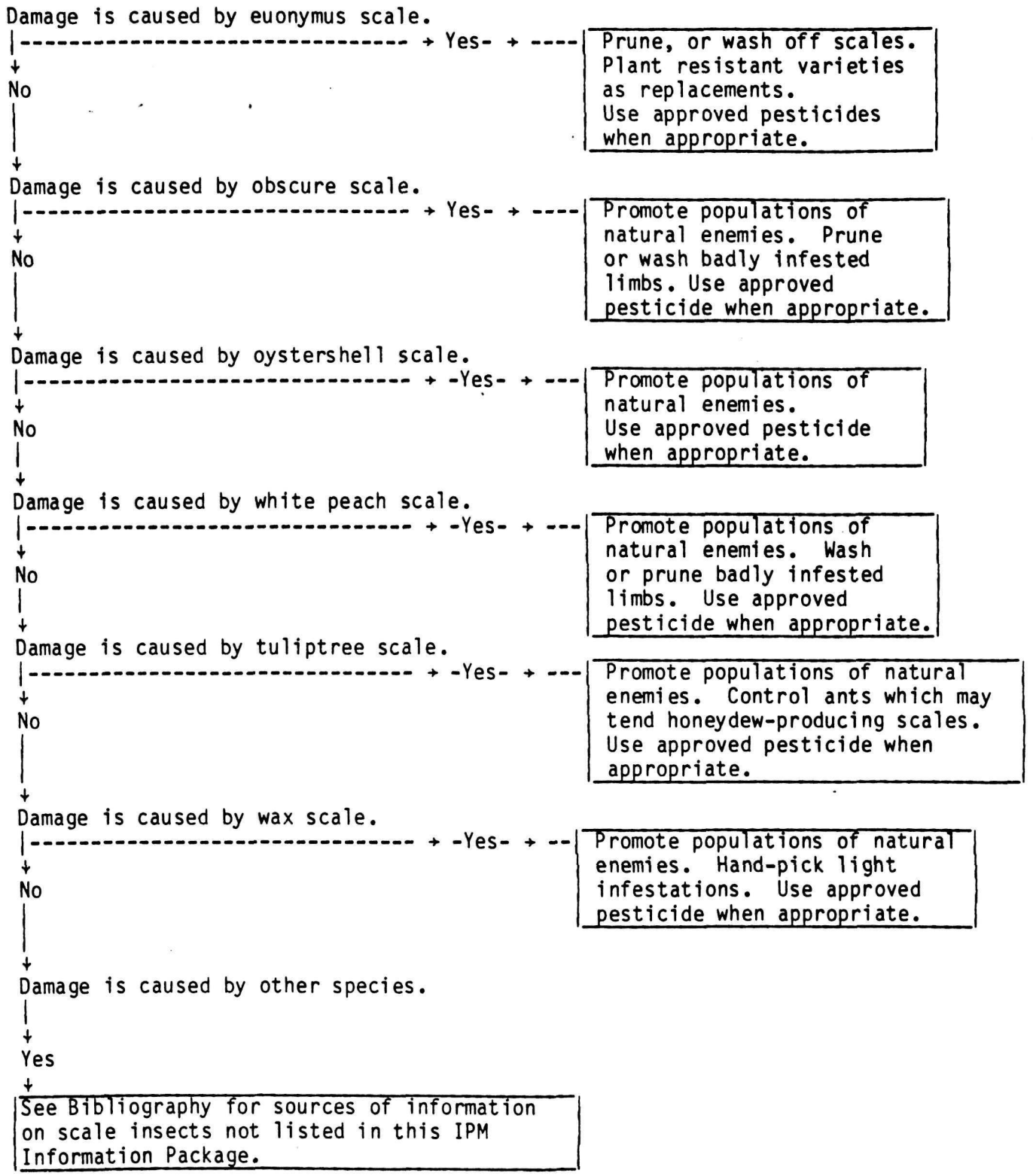
You wish to control an existing infestation of scales.

↓ Yes

Identify the species causing damage using information in this Information Package and/or sources listed in the Bibliography.

↓

See next page for specific scale pests.


Damage is caused by euonymus scale.
Yes
Prune, or wash off scales. Plant resistant varieties as replacements. Use approved pesticides when appropriate.
No
Damage is caused by obscure scale.
Yes
Promote populations of natural enemies. Prune or wash badly infested limbs. Use approved pesticide when appropriate.
No
Damage is caused by oystershell scale.
Yes
Promote populations of natural enemies. Use approved pesticide when appropriate.
No
Damage is caused by white peach scale.
Yes
Promote populations of natural enemies. Wash or prune badly infested limbs. Use approved pesticide when appropriate.
No
Damage is caused by tuliptree scale.
Yes
Promote populations of natural enemies. Control ants which may tend honeydew-producing scales. Use approved pesticide when appropriate.
No
Damage is caused by wax scale.
Yes
Promote populations of natural enemies. Hand-pick light infestations. Use approved pesticide when appropriate.
No
Damage is caused by other species.
Yes
See Bibliography for sources of information on scale insects not listed in this IPM Information Package.

II. SCALE INSECT BIOLOGY AND ECOLOGY

1. Species Described:

Scales are members of the order Homoptera, which includes aphids, whiteflys, plant and leaf hoppers, and cicadas. Armored scales (Diaspididae) and the soft scales (Coccidae) are among the most important pests of ornamental shrubs and trees. Scales do not resemble most other insects in that the adult females are degenerate (having lost legs, wings, and other body parts) and are sessile for their adult lives. Scale covers are composed of wax and proteins (armored scales) or wax only (soft scales).

Scales feed on plant sap by piercing the phloem tissues with their long, stylet-like mouthparts. Their feeding deprives the host plant of food manufactured in the leaves.

While many species of scale insects damage plants in the United States, this package describes in detail the life histories and management of several of those which NPS has found to be especially important within the National Park System. Photographs and further information concerning these and other scale insects may be found in publications such as Johnson and Lyon (1976).

The following descriptions refer to adult female, and immature male scale covers of 6 species of common scale insects. Adult male scales are tiny, fragile, and gnatlike. They have 2 wings. Refer to the life history sections for descriptions of eggs and crawlers (first instar nymphs which are the motile stage).

Consult your regional IPM coordinator for assistance in identifying scales in your area.

1. Euonymus scale - Unaspis euonymi (Comstock). An armored scale. Male scale covers are elongate, whitish, 1-1.5 mm long with 3 longitudinal ridges. Female covers are brown, broadly oyster-shaped, 2 mm long.

2. Obscure scale - Melanaspis obscura (Comstock). An armored scale. Female covers are gray and circular, about 1 mm in diameter. Females tend to cluster in overlapping colonies. Males are extremely rare. Male scale covers are gray and oval.

3. Oystershell scale - Lepidosaphes ulmi (L.). An armored scale. Adult female covers shaped like oyster or mussel shells. Two forms: the banded or "lilac" form is brown with lilac colored bands; the brown or "apple" form is solid brown. Both forms are about 2.5 mm long. Male covers are white, about 1.5 mm long.

4. White Peach scale - Pseudaulacaspis pentagona (Targioni-Tozzetti). An armored scale. Adult female scale covers are 2-2.5 mm in diameter, convex, grayish white. They are often covered with a thin layer of the outer bark skin. They are semi-circular, but shape may vary with scale density. The orange-yellow exuvia (anal plate) is in the center of the cover. The insect itself is creamy white to reddish orange. Male scales are pure white, with light yellow exuvia, and about 1.5 mm in length. They tend to form cottony clusters on heavily infested branches and on lower and older portions of tree. The adult male is seldom observed.

5. Tuliptree scale - Toumeyella liriodendri (Gmelin). A soft scale. Young adult female covers are pink and somewhat flat. Older adult female covers are highly convex, orange, and mottled with black. They are 6-12 mm in diameter. One of our largest soft scales.

6. Wax scale - Ceroplastes ceriferus (F.). A soft scale. Look like large white or cottony drops of wax, and are sticky to the touch. Up to 5 mm or larger in diameter. The adults are highly convex, immatures are "dunce cap" shaped, with the dorsal nipple pointed forward.

2. Geographic Distribution:

1. Euonymus scale - Worldwide except Australia. Common throughout range of its primary hosts.

2. Obscure scale - Native species. Eastern U.S. (except northern Maine) west to a line extending from western Texas north to North Dakota - Minnesota border, north into Canada. See Stoetzel and Davidson (1973) for detailed range map.

3. Oystershell scale - Worldwide in temperate regions. Most common in U.S. in New England and Great Lakes states. Introduced from Old World.

4. White Peach scale - Worldwide, introduced from Orient. Throughout U.S. on suitable hosts.

5. Tuliptree scale - Native species. New York and Connecticut to Florida, west through Mississippi River Valley. Introduced into California. See Burns and Donley (1970) for detailed range map.

6. Wax scale - Worldwide. Common in the southern U.S. as far north as North Carolina and north to Maryland along the Eastern Seaboard.

3. Habitat:

1. Euonymus scale - Females on stems and leaf veins of host plant. Males occur throughout surface area; may whiten entire plant.

2. Obscure scale - Common on trunk and large limbs of host trees. Most common on hosts planted in urban areas. Uncommon to rare in forests.

3. Oystershell scale - On bark of twigs and branches where it often forms large populations. Sometimes found on leaves and fruit.

4. White Peach scale - Male scales cluster on lower and older portions of host plant. Female scales found over entire plant, but seldom on terminal green wood (if found there, usually on buds). Females settle on brown wood from previous years growth.

5. Tuliptree scale - Found on seedlings, branches of midsized trees, and small adventitious twigs of all sized yellow-poplar trees.

6. Wax scale - Found on stems and branches of host plants, never on leaves.

4. Hosts:

1. Euonymus scale - Feeds primarily on Japanese euonymus (Euonymus japonica) which is heavily damaged and extremely susceptible. This scale is also reported from camellia (Camellia), boxwood (Buxus), bittersweet (Celastrus), daphne (Daphne), eugenia (Eugenia), ivy (Hedera), mallow, cotton, and gumbo (Hibiscus), hollies (Ilex), jasmine (Jasminum), privets (Ligustrum), honeysuckles (Lonicera), pachistima (Pachistima), Asiatic pachysandra (Pachysandra), horse-nettle (Solanum), and cherries (Prunus) (Johnson and Lyon, 1976). Euonymus sieboldiana (= kiautschovica) is resistant to this scale.

2. Obscure scale - Feeds primarily on oaks. There are two different forms (may be two different species); one feeds on trees in the red oak group, the other feeds on trees in the white oak group. Pin and willow oaks are preferred hosts. Non-oak hosts include pecan, beech, and chestnut.

3. Oystershell scale - Wide host preference; over 125 species are known hosts. Preferred hosts include: lilac, ash, willow, poplar, maple (banded form); apple and dogwood (brown form). Other common hosts of both forms include: boxwood, birch, beech, cotoneaster, elm, horse chestnut, linden, mountain ash, pachysandra, pear, plum, sycamore, tuliptree, viburnum, Virginia creeper, and walnut.

4. White Peach scale - General feeder; over 97 hosts listed (Kuitert, 1968). Preferred hosts include: peach, cherry, mulberry, chinaberry, persimmon, plum, holly, apple, and privit. The host list includes such diverse plants as geraniums and tung oil tree. Most serious on Japanese cherry and peach.

5. Tuliptree scale - Preferred hosts are tuliptree (Liriodendron tulipifera) and Magnolia soulangeana. Also reported from linden (Tilia spp.), Southern magnolia (M. grandiflora), and star magnolia (M. stellata). Several other hosts in Florida (See Johnson and Lyon [1976] for lists).

6. Wax scale - General feeder; over 50 known hosts. Preferred hosts include: Burford, Chinese, Japanese, and English hollies; spirea; pyracantha; euonymus; and hemlock.

5. Life Cycles:

1. Euonymus scale - Overwinter as gravid adult females. The eggs are deposited in early spring beneath the female scale cover. Eggs hatch over a period of 2-3 weeks beginning in early June in the Northeast, late May in the Mid-Atlantic region. Crawlers (young nymphs which are the only mobile stage) move to other parts of the host or are wind dispersed to other host plants. There are 2 generations per year in the Northeast, 3 in the southern range. Crawlers are present in May, July and September.

2. Obscure scale - On red oaks, there is one generation per year. Overwinter as adult females and immature males. Males mature in April, and emerge in last 2 weeks of May; they live less than 24 hours. Females become adults from the end of April to early September, and oviposit from early July to early September. Peak crawler populations are in mid-July. Crawlers are wind dispersed up to 80 feet.

   On white oaks, the life cycle is similar, but most stages appear a month later, with peak crawler populations in mid-August.

3. Oystershell scale - Both banded and brown forms overwinter as eggs which are laid in late fall under old female covers constructed the previous summer. Eggs hatch in early to late May, depending on temperatures, over 10-14 day period. Crawlers leave old female covers and find clear space on bark to settle, feed, and construct new covers when 1 day old. Males are rare and not necessary for reproduction; females are parthenogenic. In southern part of range (Long Island and south), there are 2 generations per year; the second generation of crawlers occurs in August.

4. White peach scale - Overwinter as gravid females. Eggs are light creamy yellow to light red. When mature, red eggs will become females, pinkish white eggs will become males. Eggs are deposited over an 8-15 day period, and hatch in 2-5 days. There are 3 generations per year. Crawlers appear mid-May, late June, and late August. Males cluster on older growth, females on newer wood. Females often settle under old scale covers in heavy infestations.

5. Tuliptree scale - Overwinter on bark as second instar males and females, becoming adults in June. Males die after mating, females feed and grow throughout the summer. Each female produces up to 3600 young over a single season. Eggs hatch within the body of the female to produce live crawlers in mid-August to early November. Crawlers are black, and about 1 mm long. There is one generation per year (in the extreme southern portion of the range, reproduction occurs year-round).

6. Wax scale - Overwinter as mature females on twigs. Eggs are deposited from late April through June. Egg hatch occurs 3-4 weeks later, over a 2-3 week period. Crawlers are pink, wind dispersed, and must settle and begin feeding within 24 hours or they will die. Crawlers manufacture wax as soon as they settle. By the third instar, the wax cone is evident. Females mature by August. One female can lay up to 2,000 eggs per season. There is one generation per year.

6. Seasonal Abundance:

Scale insects, as with most other organisms, peak in population when the offspring are newly developed and before natural enemies take their toll.

1. Euonymus scale - Populations are highest when crawlers are present in May, July, and September.

2. Obscure scale - Populations are highest in mid-July, when the single generation of crawlers is present.

3. Oyster scale - Populations are highest in May and August when the 2 generations of crawlers are present.

4. White Peach scale - Populations are highest in mid-May, late June, and late August, when the 3 generations of crawlers are present.

5. Tuliptree scale - Populations are highest in mid-August through early Fall, when the single generation of crawlers is present.

6. Wax scale - Populations are highest in late June through early July when, the crawlers are present.

7. Response to Environmental Factors:

Scale populations are influenced by a wide range of factors including climate, temperature extremes, wind, snow, ice, natural enemy populations, and the availability and susceptibility of host plants. Populations are further influenced by mistimed or otherwise improperly applied control efforts aimed at scales or other insect species. Natural enemy populations are often reduced following chemical treatments, and scales often increase following the elimination of this limiting factor.

8. Impact of Scale Insects:

8.1 Direct Impact: High populations of scales damage host plants by heavy feeding on plant juices. Heavy feeding may cause severe damage in drought conditions. Many species of armored scales cause damage from the toxic effects of injected saliva. Severe attack on the leaves, stem, branches, and shoots can cause discoloration from loss of chlorophyll, deformation and splitting, retardation of growth, and general weakening of the plant. In severe cases, branches may be killed, and there may be loss of leaves, flowers, or fruit, and eventual death of the host plant following 2 or 3 years of successive attack. Plants weakened by scale attack are more susceptible to disease, attack by other insects, and winter injury.

1. Euonymus scale - In light attacks, yellowish or whitish spots occur on the leaves. When heavily infested (especially by males), the entire plant may be whitened, causing premature leaf drop and loss of plant vigor (Johnson and Lyon, 1976).

2. Obscure scale - Heavy infestations of this species cause dieback of limbs and branches.

3. Oystershell scale - Symptoms include early yellowing or browning of foliage. In heavy infestations, the entire branch may die. After several seasons of repeated attack, the host plant may loose vigor, weaken, and die.

4. White peach scale - Large populations of this scale may kill small to medium-sized branches (Johnson and Lyon, 1976). Moderate populations can affect the number and appearance of flowers and fruit. Infestations can stress trees, allowing other factors to kill the plant.

5. Tuliptree scale - Infestations cause premature leafdrop and dieback. Honeydew and resultant sooty mold may have adverse aesthetic impacts.

6. Wax scale - Attacks by wax scale cause loss of plant vigor and may kill branches after several years of attack. Wax scales, due to their large size and conspicuous shape and color, may have adverse aesthetic impacts.

8.2 Indirect Impact:

The major indirect effect of scale insects concerns honeydew produced by some species as a byproduct of feeding. Honeydew attracts ants, wasps, and flies which may themselves become pests. Ants tend honeydew producing insects and interfere with activities of natural enemies. Honeydew also supports the growth of sooty mold which blackens leaves and branches, is unsightly, may deface cars and structures below, and (if present in sufficient quantity), may interfere with plant photosynthesis by cutting off light to leaves.

9. Natural Enemies:

Scales are susceptible to attack by a wide variety of predators, parasitoids, and pathogens due to their sedentary habits, colonial distribution, general chronological continuity of all life stages in a population throughout the year, and the population stability conferred by perennial host plants (DeBach, 1974). Nearly half of all successful biological control programs yet attempted have been directed against scales.

1. Euonymus scale - Attacked by non-specialized predatory mites, lady beetles, and parasitic wasps (Dabbour, 1967).

2. Obscure scale - Several species of lady beetles including Scymnillus aterrimus, Microweisea misella, and Cephaloscymnus zimmermanni prey upon all stages of obscure scale (Davidson and Stoetzel, 1976). In addition, a predaceous thrips (Leptothrips sp.) and 14 species of predaceous mites attack this scale (Stoetzel, 1975; Davidson and Stoetzel, 1976). A pink-scale fungus (Nectria diploa) parasitizes adult females. The most common parasitic wasps are Prospaltella fuscipennis, P. berlesii, Physcus varicornis, and Ablerus clisiocampae (Davidson and Stoetzel, 1976). Obscure scale is parasitized by at least 15 species of parasitic wasp (Davidson and Stoetzel, 1976).

3. Oystershell scale - Hemisarcoptes malus, a predatory mite, attacks eggs, and sometimes other stages, including adult females. An aphelinid wasp parasite, (Aphytis mytilaspidis), controls populations in Nova Scotia (Bartlett et al., 1978).

4. White Peach scale - Preyed upon by several natural enemies, some of which have been used in successful biological control programs. The best known natural enemy is Prospaltella berlesei, an aphelinid parasite which was used to control WPS on mulberry in Italy and on oleander in Bermuda (Bartlett et al., 1978). This parasitic wasp attacks all stages of the scale but prefers young female scales. Other parasitoids which have been used in biological control programs include the eulophid wasps Aphytis diaspidis and Aspidiotiphagus citrinus. Predators of WPS include the twice-stabbed lady beetle Chilocorus stigma, and the lady beetles Lindorous lophanthae, and Exochomus childreni in Florida (Collins and Whitcomb, 1975).

   Other predators include a predatory thrips and a belbid mite (Van Duyn and Murphey, 1971).

5. Tuliptree scale - Nymphs which have survived the winter are preyed upon the the lady beetle Hyperaspis proba proba (Say). This beetle has been observed feeding on scales as early as February. Scales are parasitized by the encyrtid wasp Anicetus toumeyella beginning in late May, and by the syrphid fly Bacchia costata from mid-July to the first frost. Predaceous larvae of Laetilia coccidivora, a moth, feed on mature female scales from mid-July throughout the summer. See Burns and Donely (1970) for details.

6. Wax scale - A eulophid wasp parasite Coccophagus fraternus has been collected from wax scales, but is thought to be of minor importance in the control of this species. Caterpillars of Laetilia coccidivora moths feed upon wax and other soft scales (Johnson and Lyon, 1976).

III. SCALE INSECT MANAGEMENT

1. Population Monitoring Techniques:

Scales are best monitored by carefully examining host plants. On small plants, examine the entire plant; on larger plants and trees, examine representative sections. A 10x hand lens is particularly useful in determining the condition of populations. To determine if a scale is alive or dead, flip up the scale cover. A live scale is plump and full of body fluids; dead scales are dry and withered-looking. Scale covers with holes indicate the presence of natural enemies.

Use the attached monitoring form to record data. Pay special attention to the density of scales (number per unit area), the presence of natural enemies (determined by holes in scale covers or partially chewed covers), and the presence of eggs, crawlers, or adult males.

Monitoring is important in the determination of treatment timing. Armored scales are resistant to most insecticide sprays after the crawlers settle. They are most vulnerable during the crawler stage and for approximately 4 weeks when crawlers are manufacturing covers.

2. Threshold/ Action Population Levels:

Although scale insects are among the most serious of insect pests, few attempts have been made to set action levels for them. In some cropping systems (citrus, apples) guidelines exist, but virtually no levels have been worked out for ornamentals for aesthetic tolerances.

To set threshold/action levels in your area:

1. Carefully observe the host plants for scale.

2. Identify the scale insect pest.

3. Rewiew the pest life cycle and monitor carefully for crawlers at the correct season.

4. Determine if natural enemies are controlling the scale by examining scale covers for the relative abundance of live vs. dead scales. (A rough treatment threshold is less than 50% of scales monitored show natural enemy attack.)

5. Before considering treatment, take an overall look at the plant to decide what level of damage or scale density is tolerable on the plant.

6. When treatment is necessary, spot treat the infested areas only, if possible. Spot treatments will avoid undue impacts to natural enemy populations.

Action levels for white peach scale on Japanese cherry trees in Washington, D.C., were set at one heavily infested branch or two moderately infested branches per tree (Hackett and Giraldi, 1981). Spot treatments were carried out when that action level was reached on individual trees.

3. Management Alternatives-Nonchemical:

Nonchemical alternatives for scale control include cultural practices, selection of resistant varieties, biological control, hand picking, and washing encrusted scales with water or soap and water to flush them from the host plant.

1. Euonymus scale - At present, the best nonchemical control for this scale is the substitution of resistant euonymus varieties for Euonymous japonica. E. kiautschovica (sieboldiana) and E. petunica are both resistant species, even when grown among heavily infested E. japonica (Johnson and Lyon, 1976).

2. Obscure scale - Tree vigor should be maintained; healthy trees are better able to tolerate scale damage. Obscure scale is kept below injury levels in forested areas by the action of natural enemies (Davidson, 1976). Heavily infested limbs may be pruned and destroyed by burning or burial.

3. Oystershell scale - A predatory mite, Hemisarcoptes malus, introduced into Canada in the early part of this century, has spread throughout North America. This mite is highly effective in heavy infestations of oystershell scale and is dispersed by lady beetles. Reinfestation after the mite has reduced populations is often delayed by lady beetles and parasitic wasps, which keep scale populations below injury levels. Oystershell scale is often controlled by sprays used against other pests (Bartlett et al., 1978).

4. White peach scale - Nonchemical controls for white peach scale include water or soap and water washes for heavily infested limbs (Hackett and Giraldi, 1981), and pruning of heavily infested limbs in spring. Natural enemies, when not reduced by repeated treatments of organophosphate insecticides, reduce white peach scale populations below the action level. Parasites are common in undisturbed sites such as roadsides, vacant lots, and neglected orchards, while predators are better established in open areas such as fence rows and managed orchards (Collins and Whitcomb, 1975).

5. Tuliptree scale - Small infestations on seedlings and saplings can be handpicked. Heavily infested branches may be pruned. Honeydew and crawlers can be removed with water or soap and water washes. Natural enemies of this scale should be conserved by timing chemical treatments so as not to interfere with their life cycles.

6. Wax scale - Light infestations should be hand picked. Picked scales should be destroyed and not merely discarded to prevent egg development and crawler dispersion from dislodged females.

4. Management Alternatives-Chemical:

Two types of chemical treatments are usually recommended for scale insects: dormant oils in the early spring, and insecticides when crawlers are active.

Dormant oils (60- or 70- second Superior type), applied with a hydraulic sprayer to infested, oil tolerant trees and shrubs, give excellent control of most scale insects. Oils should be applied during the dormant season, shortly prior to leaf bud break. On plants susceptible to oil, a dormant treatment with liquid lime sulfur may be substituted (Davidson, 1979).

Dormant oil treatment is not recommended for the following trees: Japanese maple, sugar maple, beech, birch, hickory, walnut, butternut, Douglas fir, blue spruce, and most other conifers. Oil may cause severe injury to leaves and bark of sensitive plants. Read the label to determine when and on what plants oil can be safely used.

Do not use oil on plants suffering from moisture stress or when the temperatures are below 7°C (45°F) or above 30°C (85°F).

Do not use oil on foliage within 30 days before or after using sulfur treatments for fungi. See Moore et al. (1979) for further details regarding use of dormant oil.

Insecticide sprays for crawlers are not as effective as dormant treatments. Crawler treatments must be carefully timed in order to affect the maximum numbers of crawlers and the smallest number of natural enemies. When crawler treatments are necessary, 2 treatments, approximately 10 days apart are recommended to provide maximum effectiveness.

Chemical treatments for other pests must be carefully timed as well in order to avoid affecting natural enemy populations of scales. In many cases, scale outbreaks are triggered by control programs directed at other insect or weed pests.

Insecticidal soaps have been used with success against crawlers (Hackett and Giraldi, 1981). Soap treatments must be carefully timed and repeated, if necessary, due to lack of residual effects.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Monitor scale populations beginning in early spring. A 10x hand lens is a useful monitoring tool. Note when eggs, crawlers, and male scales are present; times will vary from region to region. See Davidson (1979) for approximate dates for the Central Atlantic area, and determine the approximate date for your area by observation. Note percentages of live vs. dead scales to determine the effectiveness of natural enemies.

2. Set injury levels based on the relative importance of plants; an ornamental planting, specimen plant, or historic tree will have lower tolerance to injury than trees in recreational or forest areas.

3. Reduce heavy scale infestations, if feasible, by washing or pruning infested limbs.

4. Conserve natural enemy populations. Time insecticide applications to avoid disrupting natural enemy populations. Plantings of nectar-bearing flowers nearby attract and maintain many natural enemy species.

5. Spot treat with approved insecticides when necessary.

6. Use dormant oil, when appropriate, to reduce overwintered scale populations.

7. If sooty mold is a problem, consider control of the ants which tend scales and prevent natural enemies from controlling scale populations.

8. When designing new plantings, or when replacing old or dead plants, use resistant cultivars or other plant species.

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V. SCALE INSECT SAMPLING FORM

DATE: PARK, AREA:

RECORDER:

HOST PLANT: PLANT SIZE (DBH, HEIGHT, ETC.)

SCALE SPECIES:

LOCATION OF SCALES ON HOST PLANT:

LIFE STAGE OF SCALE: CRAWLERS PRESENT?: Y N

DENSITY OF SCALE:
WHOLE PLANT:
PLANT PART (LEAF, BRANCH, ETC.)
AREA SAMPLE (# SCALE /SQ. INCH):

%LIVE SCALES:

DAMAGE TO PLANT OBSERVED:

TREATMENT RECOMMENDATION:

TREATMENT ACTION:

DATE OF ACTION:

NOTES:

NATIONAL PARK SERVICE
IPM Information Package

SILVERFISH

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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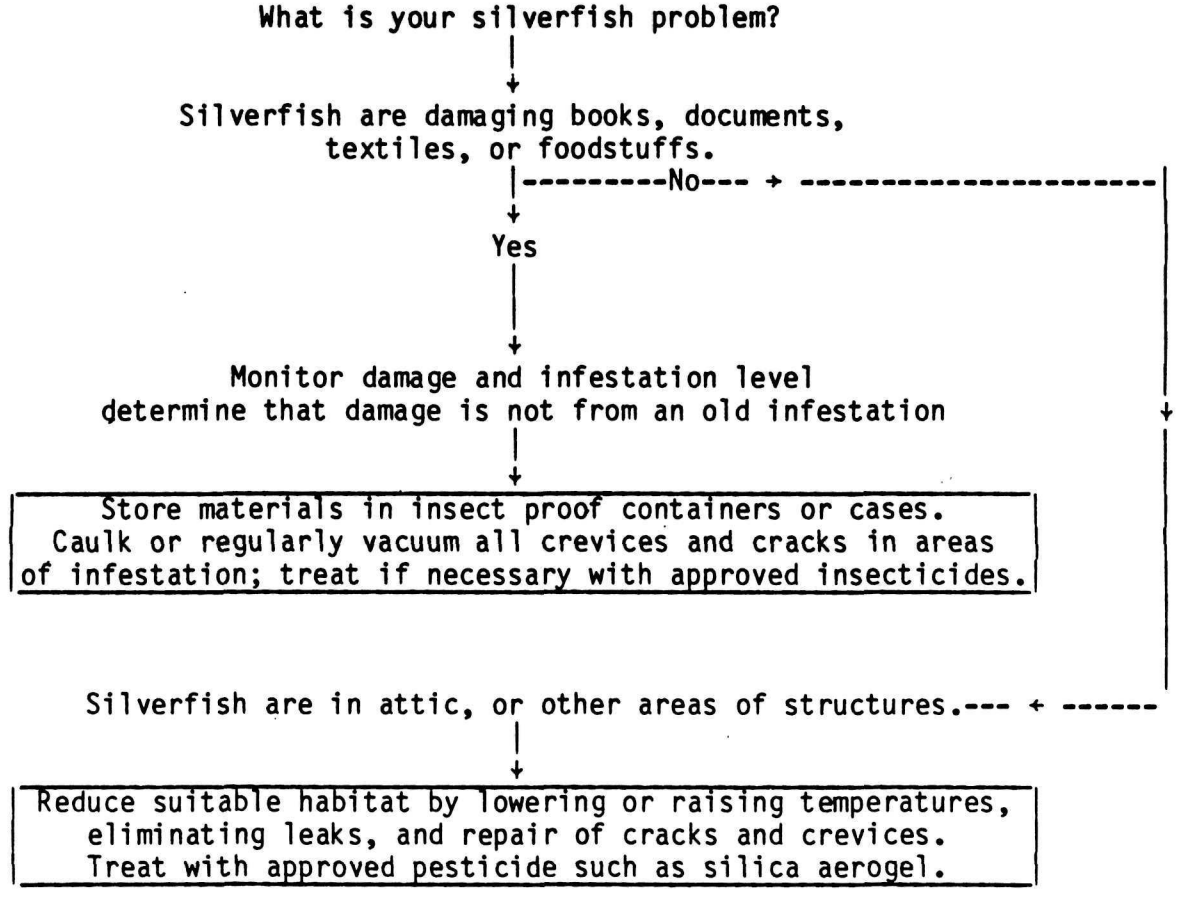
I. SILVERFISH IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. BIOLOGY AND ECOLOGY OF SILVERFISH

1. Species Described:

The term silverfish is used for the order Thysanura and for any of the species within the order.

Thysanurans have a distinct carrot shaped body, short legs, long slender antennae and three tail-like appendages (anal cerci) at the end of the body. Silverfish are wingless with sacle covered bodies which are about 1/2 inch long. Nymphs resemble adults.

There are 13 species of silverfish (Thysanura) in the U.S. Mallis (1982) lists 6 species which may be pestiferous:

A. Firebrat - Thermobia domestica (Packard)

B. (no common name) - T. campbelli (Barhart)

C. Silverfish - Lepisma sacchrina L.

D. Fourlined silverfish - Ctenolepisma quadriseriata (Luccas)

E. Gray silverfish - C. longicaudata Escherich (C. urbana in some texts) (Giant silverfish)

F. (No common name) - Acrotelsa collaris (Fab.)

See page 45 of U.S. Department of Health, Education, and Welfare (1967) for pictorial keys to common species. See also Mallis and Caur (1982) for detailed descriptions of pest species.

2. Geographic Distribution:

A. Firebrat - Worldwide in warm climates. Found in U.S. indoors, occasionally outdoors in West and Southwest.

B. T. campbelli - Found indoors in Ohio and Pennsylvania

C. Silverfish - Common indoors on East Coast, also found indoors in Midwest and Pacific Coast.

D. Fourlined silverfish - Common on East and West Coasts and in Midwest. Lives indoors, and occasionally outdoors

E. Gray silverfish - South, Midwest, and southern California (indoors only).

F. A. collaris - Recently introduced into Florida, probably from New or Old World tropics.

3. Habitat:

A. Firebrat - Prefers heated buildings. Commonly found around ovens, bakeries, and other warm areas. (Prefers temperatures above 90°F.)

B. T. campbelli - Found indoors in libraries. Little is known about its habits.

C. Silverfish - Indoors. Found in warm, humid areas, especially basements.

D. Fourlined silverfish - Often infests attics, particularly if roof is of wooden shingles. May be found outdoors in summer.

E. Gray silverfish - Indoors only. May prefer drier areas than common silverfish such as crawl spaces and attics. May occur around water pipes in bathrooms.

F. A. collaris - Found in Florida. Little is known about its habits.

4. Hosts:

Feeding habits of silverfish species are very similar. Once a source of food is located, silverfish remain in the vicinity.

Silverfish feed on human foods, especially those containing starch or flour, as well as on paper, especially glaze-coated paper. They eat sizing on paper, as well as glue and paste. They may feed on wallpaper or the paste behind it causing it to become detached from the wall.

Materials such as writing paper, tissue, onion skin paper, and cellophane are preferred as well as cotton, rayon, and other vegetable textiles. Newsprint, brown wrapping paper, and most cardboards are seldom eaten. Silverfish feed on bound volumes for the paper, the starch and sizing in the bindings, and linen bookcovers. Stored papers, books, etc. are especially susceptible. Sizing and glue are main attractants, especially if humidity is high. Wool and other animal based textiles are seldom fed upon. Cereals may become infested due to the insects' preference for starches and flour. Cellulose in paper or other wood products is broken down by enzymes and cellulose-digesting bacteria in the gut. Silverfish can live for nearly a year without feeding.

Firebrats may become serious pests in bakeries and in areas where starches are stored in warm temperatures such as warehouses.

5. Life Cycles:

A. Firebrat - Females deposit eggs in crevices. The number of eggs per batch ranges from 1 to nearly 200, averaging 50. Each batch of eggs is separately fertilized. Stressed females lay fewer eggs. Eggs hatch in 12-13 days under optimum conditions. Newly hatched nymphs are 2 mm long, white and scaleless. Development is rapid, with only 1 day spent in the first instar and more time passing between successive instars. A firebrat may pass through 45 to 60 instars during its lifetime. Later instars may last up to 2 weeks. Nymphs resemble adults. Females produce one batch of eggs per instar beginning at about the 12th week but can begin to oviposit at 6 weeks of age at temperatures of 90-106°F (32-40°C). Fertilization is external. Injured appendages are regenerated with each instar. Firebrats can live up to 2 years at warm (90-98°F) temperatures.

B. T. campbelli - Little is known of this species but its life cycle resembles that of the firebrat.

C. Silverfish - Eggs are deposited in crevices or under objects singly or in groups of 2 or 3. The female deposits 1-3 eggs per day or at irregular intervals of up to several weeks depending upon availability of food. Eggs hatch at temperatures of 72-90°F (22-32°C). Eggs hatch in 43 days at 72°F to 19 days at 90°F. Females may reproduce at 3-4 months of age. Nymphs are 2 mm in size and scaleless when hatched. Scales develop in the 3rd instar. The first instar lasts 7-10 days; successive instars are 2-3 weeks long. Adults may live up to 3 1/2 years, but most live 2 years under favorable conditions (72-80°F, RH 75-97%). Silverfish may pass through up to 50 instars in their lifetimes.

D. Fourlined silverfish - Life cycle is similar to that of the silverfish but not as limited by temperature and moisture.

E. Gray silverfish - Eggs are deposited in cracks in groups of 2-20. Eggs hatch in about 60 days at room temperature. Nymphs are scaleless when hatched. Scales appear in the 4th instar, sexual maturity is reached in 2-3 years. This species may live up to 5 years.

F. A. collaris - Little is known of life cycle; may resemble that of silverfish.

6. Seasonal Abundance: In heated buildings, silverfish are limited only by food. Numbers vary little throughout the year. Silverfish may enter buildings by way of boxes, books, or other materials carried inside.

7. Response To Environmental Factors: Temperature is the most important factor influencing the thysanurans. Low temperatures result in high mortalities, especially among nymphs. Mallis (1982) reports that temperatures below freezing or above 112°F result in 100% mortality in firebrat nymphs. Similar ranges can be expected for other species. Low relative humidities may reduce population growth or eliminate silverfish.

8. Impact: Thysanurans are primarily important as archival pests although they may infest foodstuffs. Individuals are long lived and reproduction is moderate. Populations grow slowly, but large populations can cause severe damage to paper and paper products.

9. Natural Enemies: No information concerning natural enemies of the Thysanura was found.

III. SILVERFISH MANAGEMENT

1. Population Monitoring Techniques:

Monitoring is best performed by detecting damage caused by silverfish (Mallis, 1982).

Book binding will show minute scrapings. The sizing of paper will be removed in irregular fashion and the edges of the paper will appear notched. In cases of severe injury, irregular holes will be eaten directly through paper. Other signs of feeding include feces, scales, and small yellow stains.

Active infestations can be detected by observing the small, dark feces which are visible to the eye as well as scales which are visible through a hand lens (Mallis and Caur, 1982).

A piece of paper may be coated with a thin layer of flour paste and placed in areas of suspected infestation for a week. If silverfish are in the vicinity, the paper will show feeding marks.

A small jar (baby food jars are good) coated on the inside with a thin dusting of flour and with tape or soft paper on the outside (to provide a climbing surface), placed in an area of suspected infestation, may be an effective monitoring trap for most silverfish. (Mallis and Caur, 1982).

2. Threshold/ Action Population Level:

Due to their small size and reclusive nature, silverfish are seldom seen. One adult captured in a jar trap or feeding signs on flour cards may be indicative of a population which requires control.

3. Management Alternatives - Non-chemical:

Warm temperatures and high relative humidities favor most silverfish populations. Controlling or eliminating moisture in areas infested with silverfish can reduce populations as silverfish are usually indicative of a moisture problem. Use of air conditioning or a dehumidifier to lower temperatures and relative humidities, particularly where paper or books are stored, can also help to reduce populations by lowering the reproductive rate.

Sealing cracks and crevices where silverfish hide and breed also reduces populations by reducing suitable habitat. If sealing or caulking are not possible, cracks and crevices (particularly around bookcases) should be regularly vacuumed to pick up eggs, nymphs and adults. Good sanitation practices should be followed; all valuable paper products such as books and documents should be placed in tightly sealed containers or cabinets. If this is

not possible, access by silverfish to potential food sources should be cut off by the removal of food and breeding sites such as empty cardboard boxes and other scrap paper.

Baited traps have not been shown to be effective in control due to the limited attraction of baits; direct contact by antenna is required before feeding commences.

4. Management Alternatives - Chemical:

The following pesticides are recommended for use on silverfish in NPS areas.

- Silica aerogels
- Boric acid
- Diazinon
- Dichlorvos
- Pyrethrins

Silica aerogels such as Dri-die 67® or Dryone® have been used with excellent results. Boric acid is also effective.

Pesticides for silverfish should be applied in the same manner and with the same thoroughness as for cockroaches; boric acid should be spread thinly in areas where silverfish may be present. Cracks and crevices should be treated. Programs for roach control often eliminate silverfish as well (Ebeling, 1977).

Silverfish found in attics should be treated with silica aerogels which give lasting control in dry areas.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Routinely monitor in high risk areas by looking for damage, droppings, and scales, or place flour paste baits or jar traps.

2. Sanitation: reduce harborage by enclosing vulnerable and valuable materials in insect-tight containers.

3. Reduce relative humidity or raise or lower temperatures.

4. Provide chemical control with approved pesticides.

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NATIONAL PARK SERVICE
IPM Information Package

SLUGS AND SNAILS

Final Report

4 January 1985

Submitted To:

Gary Johnston
U.S. National Park Service
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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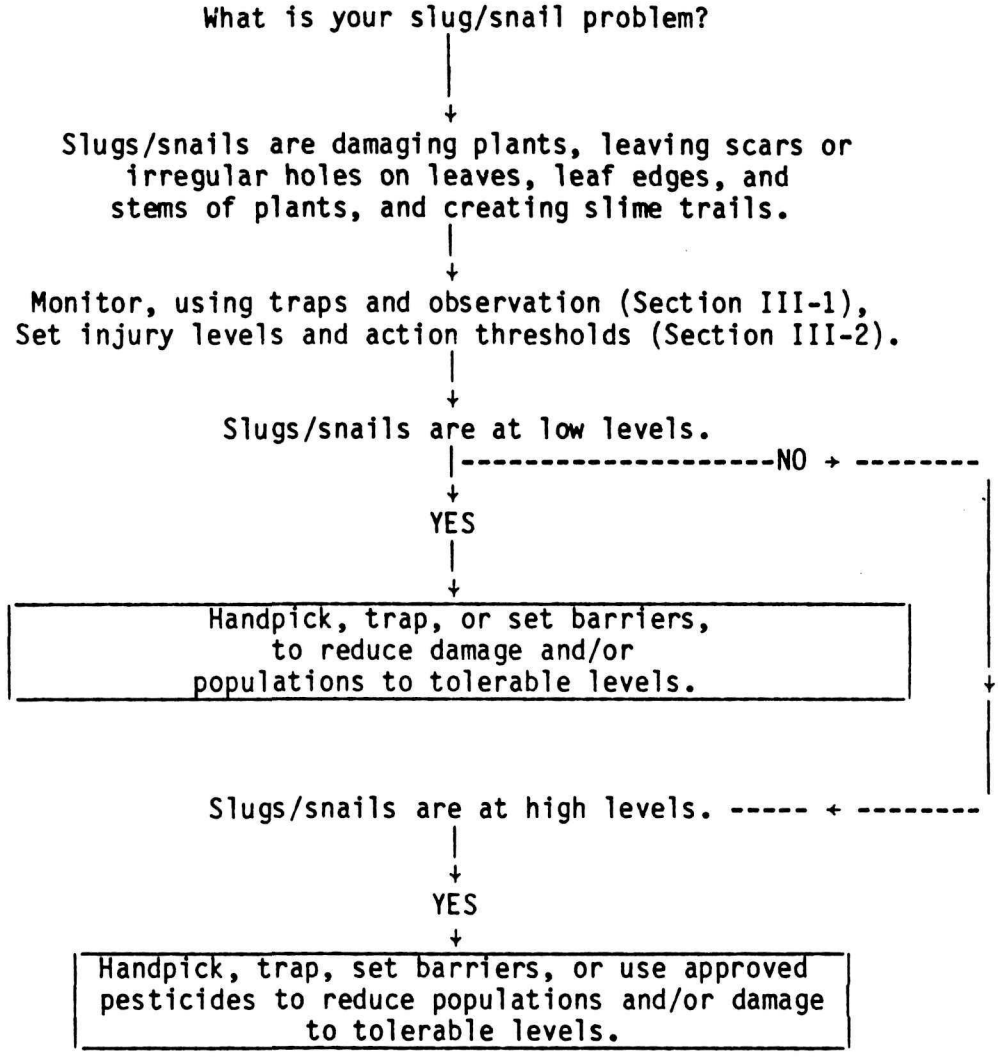
I. SLUG/SNAIL IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. SLUG/SNAIL BIOLOGY AND ECOLOGY

1. Species Described:

Snails and slugs are mollusks, members of the class Gastropoda (the single-shelled mollusks), in the order Stylommatophora. Slugs can be thought of as snails without shells or with shells (mantles) which have been reduced and internalized.

Snails have 2 pairs of tentacles: a large pair with eyes at the tips, and a smaller pair with nostrils at the tips. The mouth is in the center of the head, below the lower pair of tentacles. Below the mouth is the mucus or slime gland. The shell is formed over the visceral hump which contains the internal organs. The shell is formed by the mantle, which forms a fold where the shell joins the body of the snail (foot). The foot contains mucus glands and muscles by which the snail crawls. Several hundred species of snails exist in North America, and it is beyond the scope of this IPM Package to discuss them all. The following species were selected as being among the most important pest species.

1. Brown garden snail - Helix aspersa Muller. The shell is grayish yellow with 5 brown bands and with 4 1/2 - 5 whorls (1 whorl in young specimens). In the adult, the shell is 1 1/4 -1 1/2 inches in diameter.

2. Banded wood snail - Cepaea nemoralis (L.). The shell is light yellow with longitudinal brown stripes. The shell diameter is approximately 1 inch.

3. White garden snail - Theba pisana (Muller). The shell is white with irregular brown markings. The shell is approximately 1 inch in diameter.

4. Subulina snail - Subulina octona (Bruguiere). A small species, less than 1 inch in diameter with a gray, elongate pointed shell.

5. Cellar snails - Oxychilus cellarius (Muller), O. draparnaldi (Beck), O. helviticus (Blum), and O. allairius Muller. These are small snails, with shells 1/2 inch in diameter, gray to brown in color, with flat coils. The 4 species are similar in appearance.

Slugs are similar to snails but lack the visceral hump and shell. The mantle (saddle) is a smooth area in the front third of the back. There are over 30 species of slugs in North America. Their life histories and distributions are not completely known. The following species were selected as among the most important pest species.

1. Spotted garden slug - Limax maximus L. Body length of this species ranges from 1 1/2 - 7 inches, with the average at 3-5 inches. Smaller or young specimens are dark gray or black. Large adults are yellow gray or brown with 3 rows of black spots from mantle ("saddle") to the rear of the body.

2. Tawny garden slug - Limax flavus L. This species is up to 4 inches in length. The color is uniformly tawny to yellowish green with lighter yellow spots. The mantle is yellow and tentacles are bluish. This species exudes a yellowish slime when disturbed.

3. Greenhouse slug - Milax gagates (Draparnaud). Body length of this species is 1 1/2 - 3 inches. The color is black to dark gray with longitudinal ridges down the body and a diamond-shaped mark in the center of the back. This species has a prominent, sharp dorsal keel which extends the length of the entire mantle.

4. Gray garden slug - Deroceras reticulatum (Muller). The body length is from 3/4 - 1 1/2 inches. The color varies from white to pale yellow, lavender, purple, to almost black. This slug usually has black or brown specks or mottling except on very dark specimens. This species exudes a milky slime when disturbed (Ebeling, 1975).

2. Geographic Distribution:

1. Brown garden snail - Found worldwide, this species was introduced as a food animal in California in 1850. This species is common in the southern U.S., where winters are mild.

2. Banded wood snail - This species is found throughout the southern U.S. This species also occurs in Utah.

3. White garden snail - Originating in the Old World, this species was introduced into California in 1914 as a food animal.

4. Subulina snail - Commonly found in greenhouses, throughout the temperate regions. This species is readily transported on potted plants.

5. Cellar snails - These species are found in greenhouses and damp cellars throughout North America.

Slugs are found throughout North America in damp places and where the temperatures are mild in summer. Their distributions and life histories are incompletely known.

1. Spotted garden slug - This species was introduced from Europe. It now occurs throughout the U.S.

2. Tawny slug - Introduced from Europe, this species is widely distributed throughout the U.S., especially in the Southeast (Ebeling, 1975).

3. Greenhouse slug - Introduced from Europe in the 1880's, this species is now widely distributed in the U.S.

4. Gray garden slug - Introduced from Europe, now widely distributed throughout the U.S., especially in humid coastal areas.

3. Habitat:

Snails and slugs are active at night or on dark, cloudy days. They become less active at lower temperatures (below 50°F, 10°C).

Snails and slugs shelter in damp or moist places under or near accumulations of rotting vegetation, piles of boards, bricks, stones, under dense, low vegetation such as ivy, or under the strap-like leaves of such plants as iris. They also may be found in drain pipes, damp cellars or basements, and on well walls.

Snails tend to remain in one area all their lives. Slugs tend to wander; the larger species may travel up to 40 feet per night.

4. Hosts:

Slugs and snails feed on a wide variety of dead and living plants. They feed heavily on succulent plants and seedlings. They are common and severe pests in gardens, lawns, and orchards, particularly citrus in California and Florida.

5. Life Cycles:

Slugs and snails are hermaphroditic; each individual is capable of fertilizing the eggs of another, and of being fertilized in turn. In some species, individuals change sex as they mature; young adults are males and become females when older.

Snails lay eggs in nests in the soil or in protected areas under objects. Eggs are laid in masses of 10-200, depending on the season and age of the parent. Incubation is dependent on ambient temperatures, but usually lasts 15-20 days. Young snails remain close to the nest, wandering farther as they grow. Snails reach maturity in 4 months to 3 years, depending on the species and conditions. Common garden snails may live up to 9 years. Outdoors, in colder regions, snails overwinter in sheltered locations.

Slugs lay eggs in masses of 25 or more under boards, trash, or other damp places. Eggs are oval, light yellow, and covered with a tough elastic membrane. Eggs hatch in 25-30 days, depending on the temperature. Eggs are deposited from early spring to late fall, and in winter in greenhouses. Young slugs normally mature in approximately 1 year, or in 2 years for the larger species. Most slugs overwinter in the egg stage, but some adults may survive mild winters in drain pipes, cellars, storage pits, well walls, or beneath trash or compost piles. Slugs and snails may be active year-round in warm regions and in greenhouses.

6. Seasonal Abundance:

Snails and slugs are most common outdoors from early spring (slugs are among the earliest garden pests) to late fall. Most snails become inactive after the first heavy frost, while most slugs are killed by heavy frost. Most snails hibernate under debris, as do some slugs in mild climates.

7. Responses to Environmental Factors:

Aside from seasonal cold, the major factor affecting slugs and snails is moisture. In dry weather, they seek out damp areas or may bury themselves in the ground. Snails may close off their shell by means of the operculum (a horny or limey plate at the entrance), and aestivate for long periods.

8. Impact of Slugs and Snails:

8.1. Direct Impact:

The major direct impact of slugs and snails is the damage caused by their feeding on ornamental and crop plants. Plants not entirely consumed are often ruined for aesthetic purposes by holes in leaves or on the surface of the fruit.

Feeding damage from slugs and snails usually consists of irregular holes in leaves, fruit, or other plant parts, and is frequently associated with slime trails.

8.2. Indirect Impact:

Indirect impacts of slugs and snails are the revulsion they cause to most people, as well as the slime trails they deposit on leaves and other surfaces. In some cases, slugs and snails have been so abundant on roadsides that they have constituted a skid hazard to vehicles.

9. Natural Enemies:

Slugs and snails are preyed upon by toads, box turtles and other tortoises, some predacious beetles and their larvae (e.g. lightning bug larvae), shrews, and birds. Ducks and geese, in particular, are considered to be effective predators of slugs (Vasvary, 1979). Larvae of flies in the family Sciomyzidae are predaceous on snails, and have been considered as biological controls for several snail-borne tropical diseases (Berg and Knutson, 1978). Snails are harvested for human consumption in many areas of the world.

III. SLUG/SNAIL MANAGEMENT

1. Population Monitoring Techniques:

Slugs and snails can be monitored by means of baited traps. Shallow saucers or jars of beer or fermented grape juice set with the tops flush with the soil surface attract snails and slugs, which fall into the liquid and drown. Honey and yeast can be added to the bait to increase effectiveness. Traps should be placed around the area at intervals of about 10 feet, and should be monitored daily to remove accidentally trapped animals.

Clay pots or hollowed-out grapefruit halves can be turned upside down to provide harborage for slugs. Boards or cabbage leaves placed around beds and between rows as resting traps are also effective. Slugs and snails hide beneath these objects during the day and can be identified, counted, and destroyed in the morning.

Keep records on trap placement and on the numbers and types of animals captured. If a trap fails to capture slugs or snails after 2-3 nights, move it to a new location. Change baits twice weekly.

Feeding damage from slugs and snails usually consists of irregular holes in leaves, fruit, or other plant parts, and is frequently associated with slime trails. Slime trails themselves provide evidence of the presence of slugs and snails, and the number of trails per unit area (e.g. per square foot) can provide a rough estimate to the relative abundance of slugs and snails.

2. Threshold/ Action Population Levels:

Levels will vary with area, crops grown (ornamentals, vegetables, orchard), and the species of slug or snail. One large spotted garden slug can cause more damage than several individuals of the smaller species. Tolerable levels of damage will be very low in situations where appearance is important. Most damage to older plants is cosmetic.

3. Management Alternatives - Nonchemical:

Sanitation (the elimination of hiding places such as trash, boards, etc.), will reduce slug and snail populations. Dense, low-growing plants such as ivy or periwinkle (vinca) should not be planted near gardens.

Because snails are rather sedentary, hand-picking will usually reduce snail populations below injury levels. Snails should be hand-picked daily with records kept of the numbers captured. After the collection frequency falls off sharply, picking can be reduced to once a week. Watering the area in the afternoon is recommended to activate snails and make them easier to locate. Slugs are not easily controlled by handpicking, due to their more migratory habits.

Traps, such as those used for monitoring, are often effective in eliminating small to medium populations of slugs and snails. Large populations may be reduced below injury levels by the use of traps. Records should be kept to determine how well traps are controlling pest slugs and snails.

Barriers of wood ashes, hydrated lime, diatomaceous earth, or Snailproof ® (a commercial product consisting of ground incense-cedar sawmill by-products) applied in bands around gardens have been shown to keep slugs and snails out by acting as repellants or dessicants. Bands should be 1-4 inches wide, and 1/2 inch thick. Bands lose most of their effectiveness when wet. See Barclay (1983) for details and comparisions of various materials.

Snail fences have been used with good results in many areas. Snail fences typically consist of wire window screening with the top inch unravelled and bent out at right angles to provide a sharp barrier over which snails and slugs cannot crawl. Fences should be 8-12 inches high and placed around areas to be protected (McLeod, no date).

Bands of 30 mesh copper screen, placed aound the base of trees in 4-8 inch widths, have been used to prevent snails from climbing into avocado and citrus trees. It should be noted that barriers are not lethal, and that slugs and snails will be diverted to other, unprotected plants.

Biological controls against slugs and snails include domestic ducks, geese, and several species of rove beetles (Staphylinidae), especially the black rove beetle (Ocypus olens), which was introduced into California in 1926. A ciliate protozoan (Tetrahymena rostrata) is under study for use against both snails and slugs.

The Decollate snail (Rumina decollata), a predatory snail, has been introduced into California and Hawaii for control of the brown snail and giant African snail (California Department of Food and Agriculture, 1981). The Decollate snail is believed to be responsible for the serious decline of native tree snail populations on Hawaii and other Pacific islands.

Contact your regional IPM Coordinator before any attempt at introduction is made in your area.

4. Management Alternatives - Chemical:

Baits for slugs and snails are available commercially. Nearly all baits are metaldehyde based. Baits are available in pellet form and should be placed under cover to reduce their attractiveness to wildlife, pets, and children.

Alum, mixed with salt of sulfate of potash and sulfate of alumina, has been used to control slugs in Australia (McLeod, no date).

Fertosan Slug/Snail Killer®, an herbal product; is said to be effective against snails and slugs while harmless to pets and livestock, but no data were found to support this claim. For information, contact: Ecology Action, 5798 Ridgewood Rd., Willits, CA. 95490.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Monitor for snails and slugs using beer traps and resting traps.
2. Handpick or trap snails, and trap slugs to reduce populations below injury levels.
3. Use barriers when feasible to prevent damage in selected areas.
4. Use approved pesticides, such as metaldehyde baits, if necessary.

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NATIONAL PARK SERVICE
IPM Information Package

SOUTHERN PINE BEETLE

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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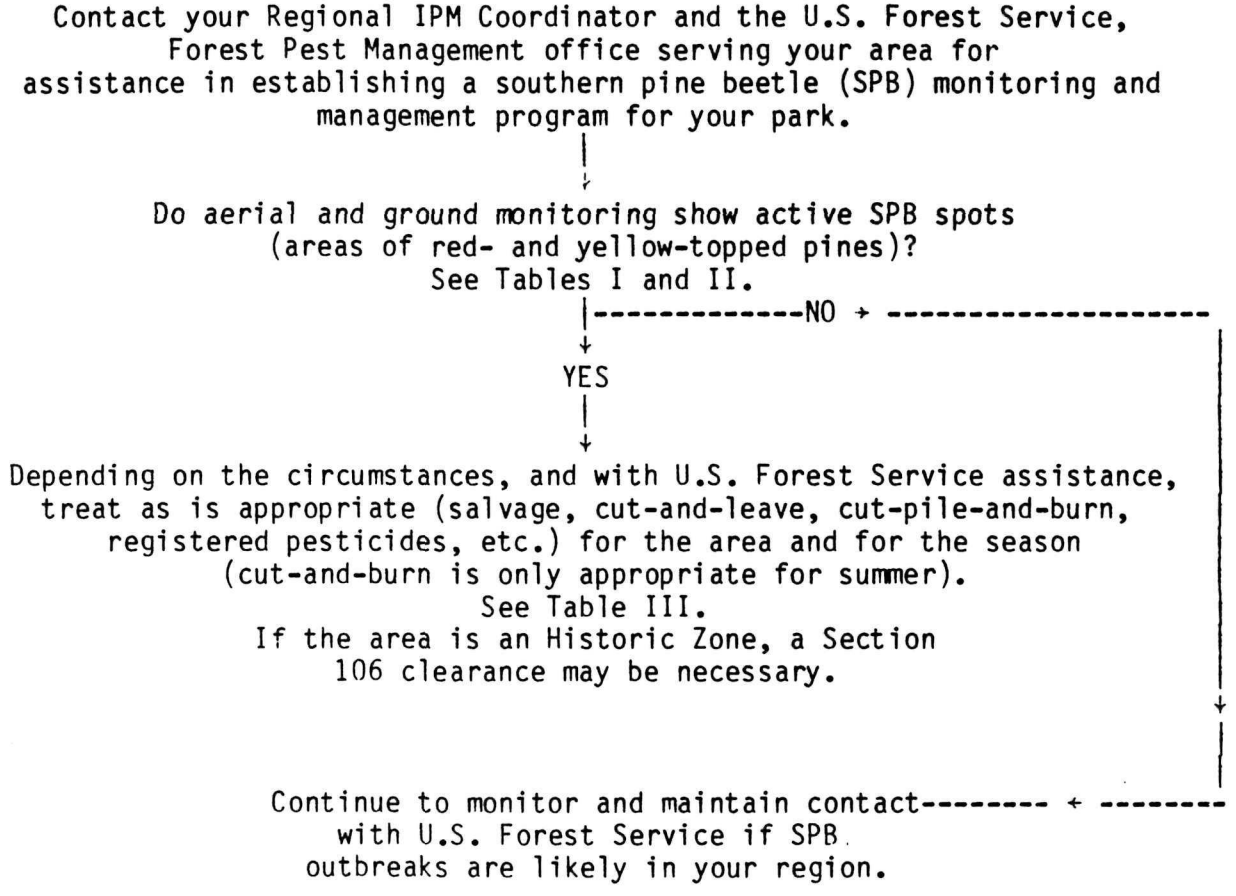
I. SOUTHERN PINE BEETLE IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All uses of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. SOUTHERN PINE BEETLE BIOLOGY AND ECOLOGY

1. Species Described:

Southern pine beetle (SPB), Dendroctonus frontalis Zimmerman, is a member of the bark beetle family Scolytidae.

Adults are small, somewhat stout, cylindrical insects 3 mm to 4 mm long. Antennae have 7 segments, and are elbowed with the outer segments enlarged and club-like. The head, partially hidden from above by the thorax, has strong gouge-like jaws (mandibles) for boring in wood. The exoskeleton is shiny and relatively smooth. Adults are dark brown to black in color.

Eggs are oval with round ends, 1.5 mm by 1 mm in size. They are yellowish white and hatch in 3 to 11 days, at temperature ranges of 15°-30°C (59°-86°F), with development faster at higher temperatures. At lower temperatures, development takes longer, up to 34 days at 10°C (50°F).

Larvae are yellowish white and go through 4 stages (instars). Each instar lasts 7-13 days. Larvae range in size from 2 mm when newly hatched to 5-7 mm in the fourth instar. Larvae feed on inner bark tissues (cambium layer).

Pupation occurs within the host tree. Pupae are yellowish white, and 3-4 mm in length. The pupal stage lasts 5-17 days at a temperature range of 15-30°C (59°-86°F), with development faster at higher temperatures. Young adults are yellowish tan in color. As the cuticle hardens, it becomes darker, a process which may take up to 14 days. The fully developed beetle is dark brown to black when it emerges from the host tree (Thatcher et al. 1981).

See Thatcher et al. (1981) for a photographic guide to all stages of the southern pine beetle.

2. Geographic Distribution:

A native insect, SPB occurs in North America in a range roughly similar to that of its preferred hosts, shortleaf and loblolly pines, i.e., south of a line from southern New Jersey to central Texas. SPB also occurs in Arizona through Central America to northern Nicaragua. In the U.S., outbreaks have occured in Texas, Oklahoma, Arkansas, Louisiana, Kentucky, Tennessee, Alabama, Mississippi, Florida, Georgia, North Carolina, South Carolina, and Virginia. Infestations have also been reported from Delaware,

Pennsylvania, Ohio, New Jersey, Indiana, Illinois, and Missouri.

See Thatcher et al. (1981), for distribution maps and information on outbreak ranges.

3. Habitat:

Attacking adult beetles bore through the bark. Egg galleries are constructed in the cambium region. The resulting larvae feed in the cambium, complete their development, and pupate in the bark. SPB initially attack the tree at mid-bole; later attacks occur above and below (Thatcher et al. 1981).

4. Hosts:

SPB can attack and kill pines of all species and all sizes. Small trees of less than 2 inches in diameter (under 15 years old) are seldom attacked. Normally, it attacks overmature trees, or stressed trees such as wind-falls, root rotted trees, or trees weakened by drought, lightning, fires, other insects, or damage caused by human activities. In outbreaks, however, SPB attacks and kills healthy pines of all species. Although the mechanisms of outbreaks are poorly understood, it is thought that poor stand vigor or stress resulting from overmaturity, drought, or ice damage from previous winters are major triggering factors.

Primary hosts are believed to be loblolly, shortleaf, Virginia, and pitch pines. Other hosts include table mountain pine, longleaf pine, spruce pine, slash pine, Norway spruce, Japanese red pine, red pine and pond pine. In Arizona and New Mexico, SPB is known to attack ponderosa and Apache pines. Secondary hosts are usually attacked only during epidemics in primary hosts. Secondary hosts do not normally support epidemics. Infestations on white pine usually do not succeed because of heavy exudations of pitch. Beetles attack red spruce, but broods do not develop within the tree (Paine, 1981).

5. Life Cycles:

In order to understand the life cycle of SPB, a brief description of the cycle of colonization is required.

In colonization, newly emerged pioneer female beetles select and attack a suitable host. Odors from potential host trees are thought to attract pioneering females. Attacking females release aggregation pheromones, principally frontalin, which, with host odors, serves to attract other females as well as males to the tree. More males than females are

attracted in this initial aggregation (4:1 or 3:1 ratio). The initial attack and aggregation is on the midbole of the tree, from 5 to 20 feet from the ground. As more females arrive, more pheromones are released, and more SPB are attracted. Attacks spread up and down the bole from the initial site. Aggregation behavior follows a diurnal pattern; in summer, greatest activity occurs around 5 PM, while in spring, peak aggregation occurs around 10 AM and 5 PM. After a female arrives, she finds a crevice in the bark and bores in, releasing frontalin and trans-verbenol which enhances the aggregation effect of frontalin. As long as the tree resists attack by exuding resin, the female releases frontalin. When the female begins to feed on bark tissues, frontalin production stops. Pitch tubes are formed by the tree as a result of cut resin ducts under internal pressure. As more beetles attack, resin pressure drops, fewer tubes are formed and the tree becomes more susceptible. When entry into the tree is complete, the female releases small amounts of the pheromone verbenone which enhances existing pheromones and orients males to entry holes in the bark. When a male finds an entrance hole, he releases verbenone and endo-brevicomin which serves to balance the sex ratio of responding SPB to more nearly 1:1 by reducing host attraction to males. As the number of males on a host increases, so does the amount of verbenone and endo-brevicomin so beetles are deterred from the host and seek adjacent host trees, beginning the process anew.

Southern pine beetles are usually monogamous, (ie. a single female will mate with a single male within the host tree) but a single female may mate with up to 6 males in some situations. Mating occurs in the entrance galleries. Once mating has occured, the female constructs an S-shaped egg gallery by expanding the entrance gallery. As she bores through the wood, she packs the debris behind her, sometimes assisted by a male. The gallery, mined in the cambium layer diagonally across the wood grain, does not branch, and may cross other galleries in heavily infested trees. Galleries range in length from 10 to 24 cm. Shortly after the egg gallery is begun, the female cuts niches in the walls and deposits a single egg within each at intervals of 1-4 cm. Up to 30 eggs per gallery may be deposited at irregular intervals.

After ovipositing, parent adults reemerge from the host tree. Reemergence occurs 1-3 days after mass attack, mating, and oviposition. Reemerged adults attack new hosts, mate, and produce more eggs.

Larvae enter the cambium layer, making galleries perpendicular to the egg gallery. Larvae then enter the inner bark and feed outward until pupation in the outer bark.

Once adult development is complete, the beetle bores through the outer bark. Emergence patterns follow a normal (bell-shaped) distribution; all of the adults of a given brood may emerge in a 10-30 day period. Adults emerge in all seasons, attacking adjacent trees or dispersing to find suitable trees elsewhere. In winter, adults may reattack the same tree. SPB overwinter in all stages of development.

Generations overlap, with newly emerging adults and reemerging adults of the previous generations attacking hosts together.

Blue-stain fungus (Ceratocystis minor) is usually found in association with SPB. Its role in the SPB life cycle is not fully understood, but experiments have shown that colonies without blue-stain fungi produce fewer eggs than normal colonies. Blue-stain and other fungi may alter the phloem and make nutrients more available to larvae.

6. Seasonal Abundance:

There are several generations per year. In the northern part of the range as few as three generations per year are produced, while in the southern part of the range, up to nine generations per year are produced. In normal circumstances, the time from egg to reproductive adult is 26-54 days. In the Southern Appalachians overwintering adults emerge in mid-April, while adults from overwintering eggs emerge in late June. In North Carolina and further south, emergence is in March.

SPB spots (local areas of infestation) expand from late spring through summer, the result of adults emerging from killed trees and attacking trees on the leading edge of the spot. SPB appears to undergo population cycles of approximately 10 years in duration. During outbreaks, SPB are abundant, killing up to 50% of the stands of pines over large areas (Thatcher et al., 1981). In other years, they are extremely rare.

7. Response to Environmental Factors:

Environmental factors are believed to trigger SPB outbreaks. The precise mechanism involved is not yet fully understood, but any factor which contributes to tree stress or loss in vigor may be a factor in outbreaks.

Lack or overabundance of water is believed to be a principal factor in outbreaks (Kalkstein, 1976). Poor drainage resulting from abundant or superabundant rains is thought to trigger SPB outbreaks on the Western Gulf Coastal Plain, while drought is a major factor on the Altantic Coastal Plain. Wet soils cause a temporary decline in vigor in host stands, while drought causes lowered resin pressures, predisposing trees to attack.

The effect of temperature on outbreaks is not fully understood, but is thought to relate to water balance in host trees. Sustained low temperatures during winter months or abnormally high summer temperatures are believed to be detrimental to brood development and survival (W. Carothers, pers. com.).

Soil composition may be an indirect factor in SPB outbreaks. High clay content in shortleaf pine stands often is a contributing factor in littleleaf disease which stresses trees, allowing successful SPB attack (Hicks, 1981). Root rot, particularly annosus rot, has been found to be a causal factor in some SPB outbreaks. Root rot results in reduced tree growth and vigor (Kulhavy et al, 1984).

High stand density or overstocking results in poor tree vigor due to intraspecific competition for available resources, and predisposes trees to SPB attack (Belanger and Malac, 1980).

Other insects, especially other bark beetles (which may be only minor pests), may stress trees, allowing SPB to colonize.

Natural termination of an outbreak may be due to one or a combination of environmental factors such as cold winters, cool wet springs, pressure from natural enemies, and lack of suitable hosts. (W. Carothers, pers. com.)

8. Impact of Southern Pine Beetle:

8.1 Direct Impact:

The major direct effects of SPB are pine mortality and the reduction in grade and yield of beetle-killed sawlogs for commercial purposes. Pulpwood can be obtained from killed trees up to 2 years after tree death with little effect on the resulting paper (Leuschner, 1981).

8.2 Indirect Impact:

Aside from aesthetic impacts, few indirect effects of SPB have been noted. There is no reduction in water quality or quantity from sites attacked by SPB, and some wildlife species actually increase due to increases in edge effect and food sources due to increased understory growth.

In recreational areas, tree mortality results in less shade and increased understory growth, causing possible reduced site use, and results in a potential safety problem. The cost of removing hazard trees may be significant. Aesthetic values and potential increased fuel loads should also be considered.

Fungi are the primary cause of death in SPB infested trees, due to their blocking of phloem tubes around the circumference of the bole, preventing flow of nutrients to the tree. Fungi are carried from host to host in the gut or on the surface of adult beetles.

Populations of red cockaded woodpeckers, an endangered species, may be affected by loss of mature pines used for nesting habitat (Hooper et al., 1980).

9. Natural Enemies:

Many natural enemies of SPB have been described, including the following:

Predators - Over 100 species of arthropod predators of SBP are known. Among the more important are:

Checkered beetle (Thanasimus dubius) adults eat attacking SPB adults, and checkered beetle larvae within SPB galleries prey upon immature SPB. Checkered beetles respond to SPB pheromones and aggregate on trees under SPB attack. A related European species (T. formicarius), introduced in 1892, was the first insect imported for biological control of a forest insect pest (Craighead, 1950).

Beetles of the genus Corticeus feed on eggs and small larvae of SPB as well as on frass and bluestain fungi.

Two anthocorid bugs (Scoloposcelis mississippensis and Lyctocoris elongatus) prey upon all immature life stages of SPB within host galleries (Schmidt and Goyer, 1983).

See Goyer et al. (1980) for descriptive keys to arthropod associates of SPB.

At least 4 species of predatory mites are considered to have impacts on SPB populations (Moser, 1975).

Birds (especially woodpeckers) are very effective SPB predators, particularly in winter. In an east Texas study, it was found that four species of woodpecker (downy, hairy, pileated, and red-bellied) caused SPB mortalities of over 60% in some instances. Woodpecker densities are up to 50 times higher in SPB infested sites than in neighboring uninfested stands (Kroll et al., 1980). The effect of woodpeckers on SPB population dynamics is currently under study.

Parasitoids - Over 35 species of hymenopteran parasitoids in 8 different families are known to attack SPB in various life stages (Thatcher et al., 1981).

Pathogens - SPB is attacked by a variety of microorganisms which kill it or reduce its fecundity. Fungi and bacteria caused an average 22% mortality in one study (Moore, 1971). One species of parasitic nematode attacks the reproductive organs of adult SPB, rendering them sterile.

Competitors - SPB survival may be reduced through competition with other beetle species such as the southern pine sawyer (Monochamus titillator), a cerambycid beetle. Individual pines are killed by competing insects, but interspecific competition may slow or prevent SPB outbreaks.

Natural enemies have a greater role in regulating SPB populations in spring and early summer than in late summer and fall (Berisford, 1981).

III. SOUTHERN PINE BEETLE MANAGEMENT

Population Monitoring Techniques:

Monitoring for SPB is a two stage process as developed by the U.S. Forest Service; an aerial survey followed by a ground survey.

Aerial Survey - Aerial Surveys show spots (areas of dead and dying pines) from the air. Expanding spots are seen as groups of trees with red and yellow crowns.

Differences in crown colors can indicate the direction of the spread of SPB infestations. In summer, bare-crowned trees (dead pines which have lost their needles) have been killed 8-12 weeks previous to observation. Red-topped trees are trees which, for the most part, no longer contain developing SPB broods, while yellow-topped trees have been more recently killed. Newly attacked trees on the leading edge of the spot are still green and indistinguishable from healthy trees.

Inactive spots have no yellow or green trees under attack, and no longer require control measures. (See Table I).

Ground checks - Ground checks for SPB should concentrate on spots designated as high and medium priority by aerial checks.

To ascertain if trees are infested with SPB, bark of red- and yellow-topped pines should be removed and inspected for the S-shaped galleries which are specific to SPB. On green-topped trees suspected of harboring SPB, and where galleries may not be fully developed, check for pitch tubes indicating entry holes and/or reddish boring dust in bark crevices, in spider webs, and on foliage of understory plants. (See Table II.)

2. **Threshold/ Action Population Levels:**

In SBP IPM, stands are rated on a risk basis. The higher the risk rating, the higher the control priority. Although risk ratings were developed for commerical timber operations, they are useful in IPM in non-timber regions.

Although it is difficult to establish thresholds, all spots of 10 or more trees should be reported. A very high percentage of spots with fewer than 10 active trees become inactive without any control.

Ground checks serve to rank stands in terms of risk and control priorities (see Table III).

3. Management Alternatives - Nonchemical:

Although southern pine beetle infestations should be allowed to occur unimpeded in natural zones, certain areas might require some management action including:

1. Areas with red cockaded woodpeckers;

2. Areas where killed trees may become hazards to visitors, park personnel, or to structures.

3. Sites where SPB infestations will kill or affect historic trees or disrupt the historic scene.

4. Infestations within the park that may spread to areas outside the park.

Most management strategies for SPB have been developed for timber producing areas. Circumstances may arise where commercial management techniques may be called for. Recommended practices include the following (treatment actions A-F are recommended for developed sites only):

A. Cultural control: Good silvicultural practices to maintain healthy stands contribute greatly to the reduction in incidence and severity of SPB outbreaks.

B. Favor most resistant species: Some pine species are more resistant to SPB attack than others, and susceptible species may change according to region. Selective cutting and replanting should favor resistant species (Belanger and Malac, 1980). See Table IV.

C. Monitoring of high-risk trees: Old pines or pines with damage from lightning, ice, hail, disease, or other disturbances, are extremely susceptible to attack and should be regularly monitored to detect any early attack (Thatcher et al, 1982). Trees in area-wide disturbances such as drought or flooding should be monitored from the air and ground for signs of early SPB attack (Belanger and Malac, 1980).

D. Maintenance of proper stand density: Thinning of pine stands increases growth and vigor, thereby reducing stress and susceptibility to SPB attack. Depending on site quality, basal areas of 80-100 ft^2/acre are recommended to reduce potential for SPB attack (Thatcher et al, 1982).

E. Management of species composition: SPB prefers pure pine stands; mixed stands of pine and hardwoods reduce chances of SPB attack. Mixed stands also support more species of plants and animals, including natural enemies of SPB.

F. Mechanical Control: Mechanical controls to stop the spread of SPB spots include the following (Billings, 1982):

1. Remove infested trees. When consistent with environmental and legal constraints, infested trees may be disposed of by commercial sale or salvage when accessible. Logging of the infested material should begin immediately. Contract time limits should ensure rapid removal.

   When practical, and if uninfested pine trees are present, a 40- to 70- foot buffer strip should be marked and cut adjacent to and ahead of the most recently infested trees. This practice is effective in reducing the possibility of "breakouts". When only a small volume of infested, merchantable material occurs in a spot, noninfested trees surrounding the spot may be marked to provide an operable cut.

   The order of priority of removing beetle-infested timber from a spot should be as follows:

   a. Trees in the buffer zone at the head(s) of the spot; if not removed within two weeks of marking, another visit and tally must be made in order to insure removal of all infested trees and an adequate buffer strip.

   b. Trees with fresh attack, and having young broods (usually the green, recently infested trees).

   c. Trees having nearly-developed broods (usually the red and fading trees).

   Remove infested trees by commercial sale or salvage procedures in accordance with National Park Service guidelines and procedures.

2. Pile-and-burn. Unmerchantable or inaccessible SPB infestations can be suppressed by cutting, piling, and thoroughly burning the bark of infested trees. The entire bark surface must be thoroughly burned to insure effective control. The order of priority for cutting, piling, and burning infested trees, particularly in the large spots, is the same as above. Cutting a buffer strip is not recommended. To reduce the possibility of "breakouts", every effort should be made to locate and treat all green infested trees during the piling and burning operation.

3. Cut-and-leave. This control tactic reduces losses from spot growth during the summer months. Cut-and-leave is designed to disrupt spot growth in small to medium-sized spots (40 active trees) by dispersing emerging beetles. These spots can be salvaged when markets or weather permit. Trees are still suitable for sale months after felling.

   The following procedure is to be followed when using cut-and-leave:

   a. Identify all active trees within the spot.

   b. Fell all active trees toward the center of the spot.

   c. Fell a horseshoe-shaped buffer of green, unifested trees around the most recently attacked trees. Leave cut trees lying on the ground with crown pointed toward the center of the spot. The buffer should be as wide as the average height of the trees in the stand.

   Cut-and-leave treatments should only be applied during the summer months (between June and October). Spots with 10 or more infested trees should be treated first. As time permits, spots with fewer than 10 infested trees should also be treated if they contain trees with fresh attacks. In these smaller infestations where a specific head is not distinguishable, an adequate buffer strip (equivalent to the avarage height of the stand) and all infested and green, uninfested trees within the spot should be felled.

   Re-examine treated areas. Re-examine areas where infested trees were removed by commercial sales or salvage, piled and burned, chemically treated, or cut and left within 2 or 3 weeks after treatment to check for additional infested trees. If additional trees are found, treat them.

In areas where infested trees have been cut or removed, stumps adjacent to living pine trees should be treated to control or prevent infestation by the root rot Fomes annosus.

In latitudes below 34 degrees N, trees cut between May and August do not have to be treated for Fomes annosus. This is because few spores are formed during this period, and high temperatures often kill spores that are produced. However, routine summer thinning in areas of SPB buildup is not recommended.

G. Biological Controls - While parasitoids, predators, and diseases of SPB play a role in reducing high populations, they alone have not been shown to terminate infestations. More likely they (in combination with abiotic factors and lack of sutiable hosts) cause infestations to decline.

Practices which favor natural enemy populations (e.g., leaving nesting snags for woodpeckers) are recommended. Evidence exists that greater numbers of predators and parasites emerge from stands treated by cut-and-leave than from standing infested trees.

4. Management Alternatives-Chemical:

SPB is a native organism and is protected in natural zones. Although NPS does not manage timber, management of SPB may be required to protect resources in Park Development, Special Use, or Historic Zones, or when SPB infestations threaten forested areas outside park boundaries. (See section III.3.)

Dursban (chlorpyrifos) is recommeded for SPB suppression in NPS areas.

The order of priority for cutting and spraying infested trees in large spots is the same as in the removal of infested trees by commercial sale. Cutting a buffer strip is not recommended. To reduce the possiblility of "breakouts", every effort should be made to locate and treat all green infested trees during the chemical control operation.

Cut, limb, and buck all infested trees into workable lengths. Spray the infested bark surface to the point of runoff. A compressed air sprayer (3-gallon capacity or equivalent) is an ideal applicator. Infested logs must be turned 2 or 3 times to insure complete treatment of infested bark. Spray stumps and bark removed by woodpeckers. Low pressure sprayers may be used to treat large, accessible infestations.

Never spray trees from which SPB brood has emerged. Natural enemies of the SPB in these trees can then complete their development.

Consult your regional IPM Coordinator to determine if pesticide treatment is recommended for your IPM program.

5. Summary of Management Recommendations:

The U.S. Forest Service provides technical assistance to other federal agencies on managing southen pine beetle. Each park manager should contact the NPS Regional IPM Coordinator and the U.S. Forest Service for assistance in setting up an IPM program for the southern pine beetle.

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Table I. SPB spot priority for ground check based on aerial surveys. (From Thatcher et al, 1982).

Priority for ground check:	Spot classification:
Priority 1 (high)	More yellow- than red-crowned trees. In dense natural pine stand or in area with past history of SPB outbreaks. Easy access or high salvageable volume. In plantation or other high value area. Threat to cross property and high value stands.
Priority 2 (breakout)	Yellow-crowned trees in spot previously reported controlled or inactive.
Priority 3 (medium)	More red- than yellow-crowned trees. Poor access or moderate salvageable volume.
Priority 4 (low)	Few yellow-crowned trees. Infested pines surrounded by hardwoods or open land. Difficult to locate on ground because of small size or inaccessibility. In unmerchantable timber or with low salvageable volume.

Table II. Symptoms associated with southern pine beetle-attacked trees in various stages of deterioration. (From Thatcher et al., 1982).

Stage	Tree part to be examined for symptoms	Symptoms or characteristics of SPB infestation
1. Trees with fresh SPB attacks	Foliage color	Green
	Pitch tubes	Soft, white or light pink
	Checkered beetles	Red, white and black adults crawling on bark
	Bark	Tight, hard to remove
	Color of wood surface	White, except close to new galleries
	Exit holes	None
	Boring dust	None to light scattering at base of tree
2. Trees with developing SPB broods	Foliage color	Green trees with larvae; needles fade to yellow before brood emerges
	Pitch tubes	Hardened, white
	Checkered beetles	Pink or red larvae about 1/2 inch long in SPB galleries
	Bark	Loose, peels easily
	Color of wood surface	Light brown with blue or black sections
	Exit holes	Few, associated with adult reemergence
	Boring dust	White, localized in areas around base of trees

Table II. (cont.)

Stage	Tree part to be examined for symptoms	Symptoms or characteristics of SPB infestation
3. Vacated trees	Foliage color	Red, needles falling
	Pitch tubes	Hard, yellow, crumble easily
	Checkered beetles	Larvae and pupae are purple; occur in pockets in loose bark
	Bark	Very loose, easily removed
	Color of wood surface	Dark brown to black
	Exit holes	Numerous
	Boring dust	Abundant around base of trees

Table III. Control priorities for SPB in timber based on risk-rating system. (From Thatcher et al, 1982).

Key to spot growth		Spot classification	Risk-rating Points
A.	Stage 1 trees (see Table II)	Absent	0
		Present	30
B.	Stage 1 and 2 trees (See Table II)	1-10	0
		11-20	10
		21-50	20
		More than 50	40
C.	Pine basal area (ft^2/a) (or stand density) at active head or heads of spot	Less than 80 (low density)	0
		80-120 (medium density)	10
		More than 120 (high density)	90
D.	Stand class by average d.b.h. (in inches)	Pulpwood (9 in. or less)	0
		Sawtimber (more than 9 in.)	10

If total is 0-30, control priority is low.
If total is 40-60, control priority is medium.
If total is 70-100, control priority is high.

Table IV. Resistance of pines to SPB attack for major geographic regions of the South. (From Belanger and Malac, 1980).

Levels of resistance	Geographic Region		
	Coastal Plain	Piedmont	Southern Appalachians
Most resistant	Slash Longleaf	Virginia Loblolly	Virginia Eastern White
Least resistant	Shortleaf Loblolly	Shortleaf	Shortleaf Pitch

NATIONAL PARK SERVICE
IPM Information Package

MITES

Final Report

10 July 1984

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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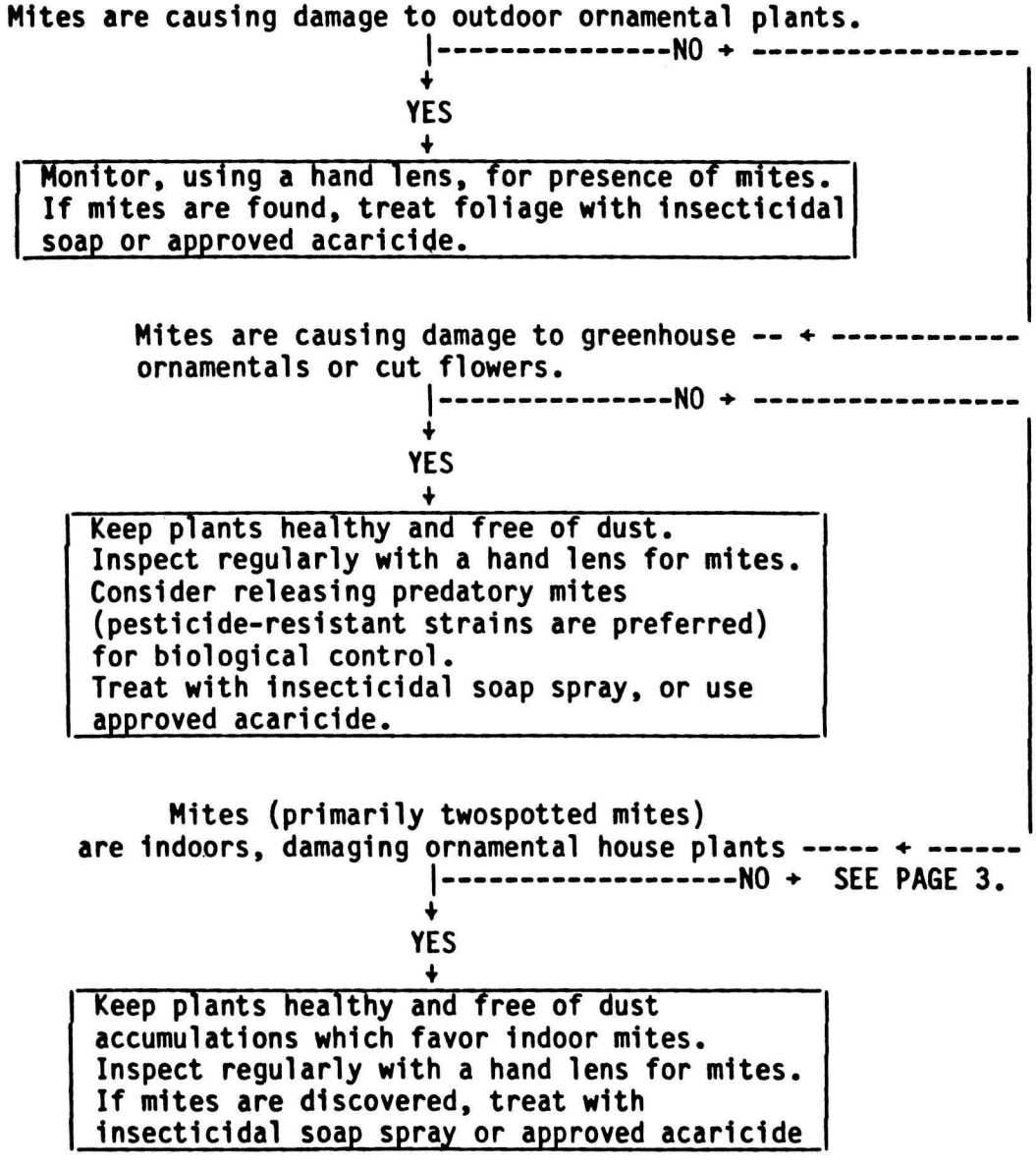
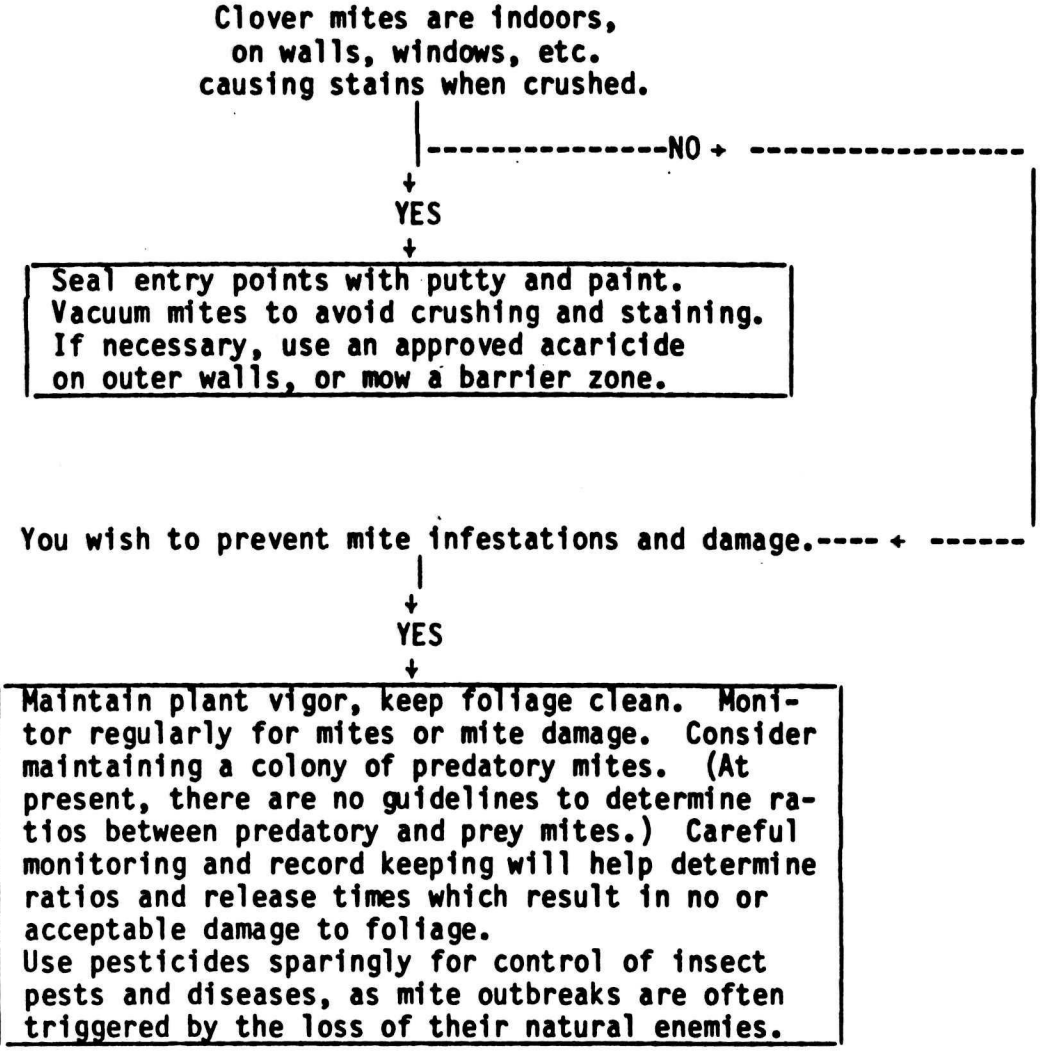
I. MITE IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




Clover mites are indoors,
on walls, windows, etc.
causing stains when crushed.
NO
YES
Seal entry points with putty and paint.
Vacuum mites to avoid crushing and staining.
If necessary, use an approved acaricide
on outer walls, or mow a barrier zone.
You wish to prevent mite infestations and damage.
YES
Maintain plant vigor, keep foliage clean. Monitor regularly for mites or mite damage. Consider maintaining a colony of predatory mites. (At present, there are no guidelines to determine ratios between predatory and prey mites.) Careful monitoring and record keeping will help determine ratios and release times which result in no or acceptable damage to foliage.
Use pesticides sparingly for control of insect pests and diseases, as mite outbreaks are often triggered by the loss of their natural enemies.

I. MITE BIOLOGY AND ECOLOGY

1. Species Described:

Mites are members of the order Acarina which also includes ticks. The mites in this package are all in the family Tetranychidae.

Tetranychid mites are extremely small, requiring a hand lens to determine their presence and numbers. Mites do not have a true head, wings, or abdomen. There are 4 pairs of legs, and a pair of leg-like palps associated with the mouthparts. Mouthparts consist of a pair of needle-like stylets (chelicerae) used to pierce cell walls, allowing the mouth to suck up cell contents. The life cycle of tetranychid mites includes the following stages: egg, larvae, nymph (up to several nymphal instars), and adult males and females. In some species, males are unknown, and reproduction is believed to be parthenogenetic (Weidhaas, 1979). Silk production by mites varies from species to species, with some producing copious amounts of silk, others little or none.

Hundreds of species of mites occur in the U.S. This package describes life histories and IPM techniques for 6 species which have been found to be of greatest concern in the National Park System.

1. Boxwood Mite - Eurytetranychus buxi (Garman). Adults are 1/2 mm long, yellow green to reddish brown. Eggs are yellow, rounded, with flattened ends. This species produces silk.

2. Clover Mite - Bryobia praetiosa (Koch). Common indoors. Adults are brownish red to red, 3/4 mm in length. Eggs are brick red, the nymphs red. This mite is easily recognized under low magnification by the long front legs which are over twice as long as the other legs, and the featherlike plates on the body. This species does not produce silk.

3. European Red Mite - Panonychus ulmi (Koch). Adult mites are 1/2 mm long, velvety red with 4 rows of curved hairs on back arising from tan or white humps (tubercles). Eggs and first instar nymphs are bright red; each egg has a single central stalk or hair. Second and third instar nymphs are dull green or brown. This species produces silk.

4. Southern Red Mite - Oligonychus illcis (McGregor). Adult females are 1/2 mm in length, blackish red, with backward curving spines. Adult males, nymphs and eggs are light red. This species produces silk.

5. Spruce Mite - Oligonychus ununguis (Jacobi). Adults are 1/2 mm in length with spines on the back, dark green or reddish green to nearly black with tan legs. Eggs are reddish tan and nymphs greenish with tan legs. Spruce mites produce copious webbing between needles of host plants.

6. Twospotted Mite - Tetranychus urticae Koch. The common "spider mite". Adults are large (3/4 mm), yellowish with 2 or more predominant dark spots on the back, which is sparsely covered with spines. Spots become more apparent as each instar matures, and less prominent following moults. Spots are accumulated food material in the digestive tract. Eggs and nymphs are lemon yellow. They live and feed beneath mats of silk webbing spun on the undersides of, and between the leaves of host plants.

2. Geographic Distribution:

1. Boxwood mite - Throughout U.S. on boxwoods, tolerant of a wide range of climatic conditions.

2. Clover mite - Throughout U.S. on suitable host plants.

3. European red mite - Throughout U.S. on suitable host plants.

4. Southern red mite - Common in Southeastern U.S., New England, Ohio, and the Great Lakes States. Particularly damaging in the deep South.

5. Spruce mite - Wide spread distribution; may be found wherever suitable hosts occur.

6. Twospotted mite - Throughout U.S., especially indoors and in greenhouses.

3. Habitat:

Habitats for the mite species in this information package consist mainly of the foliage of suitable host plants. Larvae and nymphs tend to feed on the underside of leaves, while adults and older nymphs feed on both undersides and tops of leaves as well as occasionaly on buds and shoots.

4. **Hosts:**

1. Boxwood Mite - Common pest in boxwood plantings. Attacks varieties of American and European boxwood (Buxus sempervirens). Japanese boxwood (B. microphylla) is rarely infested.

2. Clover Mite - Feeds on a wide variety of plants including clover, grasses, dandelion, iris, ivy, mallow, strawberry, peas, tomato, violet, and zinnia. A related species, the brown mite, feeds on tree foliage.

3. European Red Mite - Attacks apple and other fruits, nuts, and their ornamental varieties, as well as mountain ash. May occasionally attack elm, rose, and black locust.

4. Southern Red Mite - Attacks broad-leaved evergreens, especially Japanese holly, Pyracantha, azalea, and Camellia, as well as other hollies, laurel, Rhododendron, and other broad-leaved evergreens, especially in the deep South.

5. Spruce Mite - Attacks only conifers; primarily hemlock, spruce, arborvitae, Chamaecyparis, and juniper. Fir and pine are attacked to a lesser extent.

6. Twospotted Mite - Over 250 known host plants including flowers, foliage plants, corn and other field crops, vegetables, brambles, and other herbaceous plants. A serious pest of roses, flowering fruits, and shrubs, especially when planted outdoors after propagation in the greenhouse.

5. **Life Cycles:**

The stages in the life cycle of tetranychid mites are egg, larva, protonymph, deutonymph, and adult. Each active immature stage is followed by a quiescent state.

Spider mites have relatively rapid development and short overall life cycles, but their fecundity is not especially high for arthropods.

Because of the large number of generations in a single season, mites are noted for the rapidity with which high infestations can develop (Huffaker, et. al., 1969).

In general, mites deposit 2-20 eggs in a single day, the exact number determined by environmental factors and the species or strain involved.

Each female may produce 50-100 eggs. Some species, such as the European red mite, deposit 10-30 eggs per female for each of the first 3 generations in a season, and up to 90 per female in the fourth generation.

Sex determination in tetranychid mites is usually of the haploid-diploid type, although in some species males are unknown. Fertilized eggs develop into females, unfertilized eggs become males. Peak egg production by the female is often delayed until mating to ensure an excess of female offspring. This excess of females is thought to contribute to the rapid increase of mite populations under favorable conditions.

Tetranychid mites usually overwinter as eggs or diapausing adult females. In some species diapause is facultative, with activity and reproduction occuring throughout the year in warm climates. Diapause is determined by light levels, photoperiod, temperature, and the condition of the host plant.

Silken strands are used in "ballooning" in where a strand is spun and the wind carries the mite to another host plant. Silken mats are constructed on host surfaces to provide protection from predators and pesticides.

1. Boxwood mite - Overwinters as eggs on underside of leaves. Hatching occurs in mid-April. Early nymphs feed on undersides of leaves. Second instar mites feed on both sides of the leaf, third instars move from leaf to leaf to feed. Adults feed on shoots and upper surfaces of leaves.

2. Clover mite - Overwinters as eggs in cracks in concrete foundations, between the exterior and interior walls of buildings, and on the underside of the basal bark of trees. May also overwinter as adult females or other life stages. May become active at temperatures slightly above freezing. Eggs hatch in late winter or early spring; one generation is usually complete before mid-summer. Males of this species are unknown; reproduction is parthenogenetic (Boudreaux, 1963). Most eggs deposited by this generation aestivate until September, but some hatch in early summer and produce several small successive summer generations.

One generation is completed from aestivated eggs hatching in September. Mites may appear indoors during any warm period, but are most common from midspring to early summer. Indoor infestations have been found from November to June.

3. European red mite - Overwinters as eggs. Hatching occurs in early spring as new growth begins. Feeding activity and plant injury occur throughout spring into early summer.

4. Southern red mite - Overwinters as eggs on the foliage and twigs of its hosts. A cool weather pest, it develops damaging populations in early spring and late fall. It is thought to aestivate in the egg stage during summer, with small populations active during cool periods.

5. Spruce mite - Overwinters as eggs on the foliage and twigs of host plants. Favored most by cool weather, it tends to increase in numbers and damage levels in early spring to early summer, and again in the fall. Eggs may go into aestivation to avoid hot, dry weather. Adults may be active in summer during cooler periods.

6. Twospotted mite - Overwinters as eggs on host plants. Occurs, reproduces, and causes damage to host plants throughout the growing season. The warmer the temperature, the greater the rate of feeding and reproduction. The twospotted mite becomes especially destructive during periods of hot, dry weather, but also thrives during cooler periods.

6. Seasonal Abundance:

1. Boxwood mite - Populations are highest from early spring to early summer, with a second peak in the fall.

2. Clover mite - Commonly enters buildings in large numbers in fall.

3. European red mite - Population growth and feeding injury occur from sping to early fall.

4. Southern red mite - Populations are highest in early spring and late fall.

5. Spruce mite - Favored by cool weather, populations are highest during early spring to early summer, with a second peak in fall.

6. Twospotted mite - Populations grow throughout the growing season. The warmer the temperature, the higher the reproductive rate. Becomes especially destructive during hot, dry weather.

7. Response to Environmental Factors:

Mite populations are affected by variations in temperature, humidity, wind, and light levels. Populations of mites can be decimated by heavy rains, which wash mites from the leaves to the ground. Cool springs and summers can cause increased populations of several species.

8. Impact of Mites:

Mites are a major pest problem in agricultural and ornamental plantings. Relatively minor pests before the 1940's, mites are believed to be secondary, or triggered pests which are induced to increase their numbers to pest status by the use of many pesticides which reduce populations of their natural enemies.

8.1 Direct Impact:

Mites feed by rupturing leaf cells with a pair of needle-like stylets (chelicerae), and inserting the mouth parts to draw up the cell contents while the chelicerae are pushed deeper. Feeding causes small chloritic spots to appear which eventually coalesce. Stippling occurs and large portions of the leaf or the entire leaf becomes yellowed, bronzed, or whitened in appearance. Leaf damage on evergreens may last for several seasons; leaf damage on other plants may cause premature leaf drop, or may result in the death of the host plant.

8.2 Indirect Impact:

For most mite species, the major indirect impact is the cost to control them, and the secondary effects of pesticides used. The twospotted mite can aquire several plant-infecting viruses during feeding on infected hosts, but has not been shown to transmit them to new host plants (Orlob, 1968).

For mites which enter houses, such as the clover mite, the major indirect impact is the nuisance they cause to homeowners, and the stains they create if they are crushed.

9. Natural Enemies:

Phytophagus (plant feeding) mites are preyed upon by a wide variety of animals. Mites in the family Phytoseiidae are important predators of plant feeding mites, and have been used in biological programs for several pest species, particularly in greenhouses. Other mite families are reported as preying on plant feeding mites.

Spiders, beetles, flies, thrips, true bugs, and lacewings have all been reported as feeding on mites. Species in the lady beetle genus Stethorus are voracious predators of mites and often eliminate infestations of European red mite and spruce mite. However the control often occurs after the mite populations have peaked (Johnson and Lyon, 1976). Tetranychid mites are also susceptible to fungal and virus infections, but no pathogenic bacteria have been reported as occuring in mites (Huffaker, et. al., 1969). There are no known insect parasitoids of mites.

III. MITE MANAGEMENT

1. Population Monitoring Techniques:

Use of a hand lens is essential in monitoring for the presence of mites. Monitoring for damage alone is not recommended; in most cases, serious damage to the host plant will have already occurred. With the hand-lens, check susceptible plants for the presence of adult mites, cast skins, eggs, immature forms, and minute leaf stippling caused by feeding. Monitoring should take place at weekly intervals. Use a white card held under leaves or small branches which are then shaken or sharply rapped. Mites falling onto the card will look like a sprinkling of pepper and can be distinguished from dirt if they crawl. In winter, conifers and broad-leafed evergreens can be examined with a lens for overwintering eggs.

Determine if eggs or adults are present, alive, feeding, and if natural enemies are present in numbers. Keep records of mite numbers, season, and associated damage to determine threshold and action levels.

Although mites are best identified by experts using microscopes, reasonably adequate identifications can be made using a hand-lens, and noting the time of year, host plant species, and other salient characteristics. For positive identifications, contact local Extention Services at the nearest State University.

Other pests, most notably lacebugs, produce similar damage to foliage. To determine which pest is present, look for silk webs (misting with a spray bottle is useful in making the small webs more visible), feces, cast skins, or other signs. Lacebugs are much larger than mites and have distinctive shapes. See Hackett and Giraldi (1982) for lacebug monitoring techniques.

To monitor for clover mites in structures, examine window panes, sills, and the walls around possible entry points such as doors and windows. The conspicuous red color and relatively large size of these mites are easily observed with the naked eye.

2. Threshold/ Action Population Levels:

Due to their potential for rapidly increasing their population size, the presence of any pest mite infestations should trigger control efforts. The presence of mite damage likewise should trigger control efforts after it has been determined that active mite infestations are present.

Hamlen and Poole (1982) have developed a leaf damage index (LDI) for use on ornamental plants grown in greenhouses. Foliage is monitored on a regular basis and is graded as follows:

0 = no damage
1 = incipient damage (stippling)
2 = 1/3 of leaf area damaged
3 = 2/3 of leaf area damaged
4 = entire leaf area damaged and chlorotic.

Examine 5 leaves per plant and calculate an average value per plant. A LDI above 1.5 indicates unacceptable aesthetic damage.

Most mites in natural areas or in outdoor plantings are controlled by naturally occuring predators. Regular monitoring will determine if natural enemies are keeping mite populations and associated damage at acceptable levels.

3. Management Alternatives - Nonchemical:

Cultural controls - Certain varieties of ornamentals are resistant to mites (e.g., Japanese boxwood is resistant to boxwood mites). As with most potential problems, good horticultural techniques which reduce plant stress will also help to prevent mite outbreaks.

Mechanical controls - Use water sprays on foliage to reduce mite populations before significant damage occurs.

Clover mites which infest houses can be controlled by sucking them up with a vaccuum cleaner. This method does not leave stains on walls and carpets. Access points such as cracks and crevices should be blocked with putty and paint. In areas with severe infestations, vegetation should be kept from touching the walls by cutting or pruning a band at least 18 inches wide away from the building.

Biological controls - Predaceous mites have been used in greenhouses to control twospotted and other pest mites with good results. Predatory mites are available commercially from several sources. Predatory mites can also be reared from purchased stock in order to maintain a constant supply. See Olkowski, et. al., (1979), and Redmond (1982), for a list of commercial insectaries. Some examples of predatory mites are:

Phytoseiulus persimilis, a predatory mite used primarily in Europe to control mite pests of greenhouse grown tomatoes, cucumbers, and sweet peppers, must be released periodically for optimal control. It is used infrequently on greenhouse grown ornamentals due to lower damage tolerance levels and lack of resistance to pesticides used to control other pests and diseases (Field and Hoy, 1984).

Phytoseiulus macropilis, a related predatory mite, was found by Hamlen and Poole (1982) to give acceptible control on twospotted mite on greenhouse grown Diffenbachia when applied at a ratio of 1:10 or lower, and reintroduced every 8 weeks.

Mataseiulus (Typhlodromus) occidentalis, a predatory mite, has been developed into several strains, one of which is resistant to most organophosphide insecticides and to carbaryl. Another strain does not go into diapause under low light or short photoperiod conditions. Nondiapausing strains are preferred in that they can prey upon twospotted mites throughout the year in greenhouses. M. occidentalis is preferred for mite control for ornamentals and long term crops such as roses grown for cut flowers because it gives long term control from a single release. This predator is unlikely to bring about full control without leaf damage caused by the pest mite; therefore, application of selective acaricides are desirable in an integrated program (Field and Hoy, 1984)

Ratios of predator to prey mites which give optimal control in greenhouses have not yet been established. Most workers in the field recommend introduction of predatory mites from an established colony on a regular basis. See Olkowski et al. (1979) for details.

4. **Management Alternatives - Chemical:**

1. Insecticidal soaps such as Safer Agro-Chem®, are highly effective in controlling pest mites (Osborne, 1984). Follow label instructions for application. Insecticidal soaps are recommended for mite control in NPS.

2. Dormant and summer oils, commonly used for control of scale insects, have been reported to be effective against pest mites (Westcott, 1973).

3 Sulfur dusts, and fungicides containing sulfur, have also been reported as reducing mite populations (Westcott, 1973).

4. Pesticides registered for use on mites include the following: cyhexatin, diazinon, dicofol, and hexakis (Schwartz, 1982). Follow label instructions during application. Note that applications of pesticides often result in mite outbreaks due to the elimination of natural enemies.

5. **Summary of Management Recommendations:**

1. Monitor, using a hand lens to determine if mites are present. Do not use damage alone as a monitoring method; mite populations may build to high levels before damage is apparent, or damage may be from previous infestations which are now inactive.

2. Set action tresholds based on correlations of population sampling data and known damage.

3. Use cultural or mechanical controls to supplIment existing natural controls in outdoor situations.

4. Consider the use of biological controls such as predaceous mites for greenhouse and indoor control. Introduce biological controls on a regular, preventative basis.

5. Use insecticidal soap sprays or other approved pesticides to contol mites indoors and outdoors.

6. Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

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NATIONAL PARK SERVICE
IPM Information Package

SCORPIONS & SPIDERS

Final Report

10 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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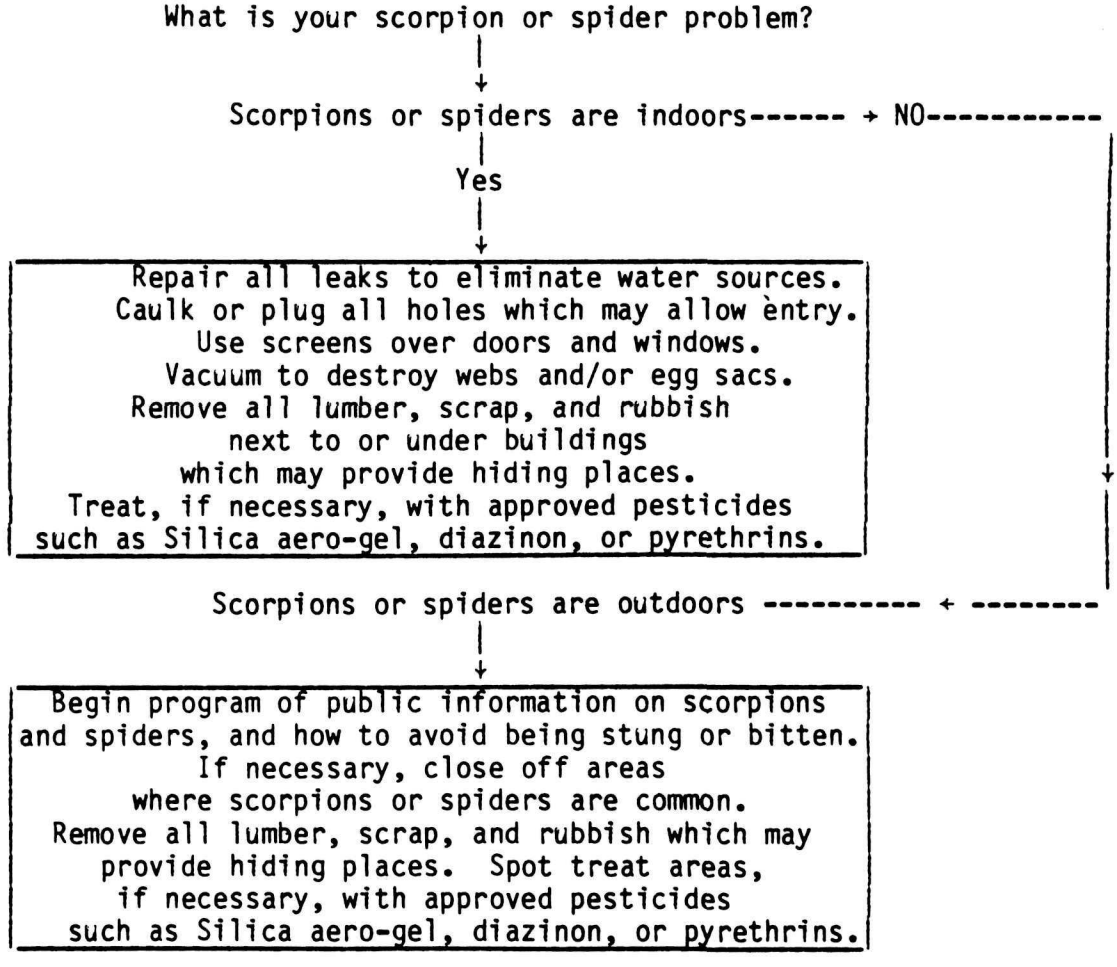
I. SCORPION/SPIDER IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II. BIOLOGY AND ECOLOGY OF SCORPIONS

1. **Species Described:** See pages 23-25 of U.S. Department of Health, Education, and Welfare (1967) for pictorial keys to common scorpions of the United States.

2. **Geographic Distribution:** In the United States, scorpions are most abundant in the Southwest in semi-arid to arid regions. Scorpions are considered rare north of a line traced from Baltimore, Maryland to St. Louis, Missouri; Salt Lake City, Utah; and San Francisco, California; but have been reported as far north as British Columbia (Ebeling, 1975).

   The sculptured scorpion (Centuroides sculpturatus) has been responsible for several deaths. It occurs mainly in Southern Arizona and parts of New Mexico, Mexico and California. Related but less venomous species occur in Big Bend National Park, Texas (C. pantherienois), and C. chisosarius). The striped scorpion (C. vittatus) ranges over the southern United States from South Carolina to New Mexico.

3. **Habitat:** Above ground scorpions (the genus Centriuroides which includes the deadly sculptured scorpion C. sculpturatus) are found in crevices in cliffs or in rock piles as well as under loose bark of trees and logs. Ground scorpions burrow in loose soil, gravel banks and sandy areas (including childrens' sand boxes). They emerge at night to hunt.

   In buildings, scorpions are commonly found in crawl spaces beneath buildings and in attics which they enter via wall voids. Scorpions require free water and are sometimes discovered in washrooms, kitchens, and bathrooms. Scorpions in buildings hide during the day in dark areas such as closets, in folded clothes, and shoes.

4. **Hosts:** Scorpions are predaceous on a wide variety of small animals including ground inhabiting insects, spiders, lizards and mice. Young scorpions feed avidly on termites. Prey is subdued by crushing with the chelae (pincers) or by rapid and repeated stings.

   Although they have 2-12 eyes, scorpions are nocturnal, and are thought to have poor vision; they can detect prey and enemies through minute vibrations detected through the chelae.

5. Life Cycles:

Females typically produce living young which ride on the mother's back for 5-15 days. Young are born in early summer following spring mating. The young molt for the first time 3-6 days after birth. After the first or second molt, young leave the mother's back to fend for themselves. They reach sexual maturity in 3-5 years.Females produce 25-39 young, with the average at 32. Scorpions may live for several years depending on the species and availability of food and water.

6. Seasonal Abundance:

Scorpion populations are relatively stable year round. They may become more abundant after the young have been born and have dispersed. Heavy rains may force scorpions to higher ground where they may become concentrated for short periods. Cold winters and cold, wet springs may reduce surviorship in the young.

7. Responses to Environmental Factors:

Scorpions are nocturnal and avoid light. They require free water and spend most of the day hiding under objects or buried in sandy soil in order to conserve moisture. They can remain buried without food or water up to 6 months.

8. Medical Importance:

8.1. Direct Effect:

Most species of scorpions inflict relatively mild stings (unless the victim is sensitive to venom). In most cases stings result in localized pain and swelling and occasionally black and blue areas near the sting site. (Envenomation should not be confused with anaphylactic shock which is a reaction to foreign protein.)

The sting from the sculptured scorpion does not cause swelling or discoloration. Typical sting symptoms include: extreme pain at the area of the sting, spreading numbness from the sting, weakness or paralysis of the injured area, hyperactivity and anxiety, profuse salivation, dizziness, difficulty in swallowing or speaking, respiratory distress or failure, and convulsions.

8.2. Indirect Effect:

The major indirect effect of scorpions on people is the fear of being stung. This may lessen the enjoyment of the outdoors in areas where scorpions are common or have been sighted.

8.3. Preventive Measures & Treatment of Stings:

Information on avoiding scorpion stings should be posted. In essence, it consists of 3 common sense principles:

1. Do not put your hands or bare feet where you cannot see. Do not go barefoot at night.

2. Shake out clothes and shoes before putting them on.

3. If you feel something crawling on your body, do not swat, a quick brush instead will remove the creature before it can sting or bite. Swatting almost always guarantees reprisal.

If someone is stung, keep the victim quiet and reassured. Although there are no first aid measures of real value in the treatment of socrpion stings, ice should be placed over the wound to reduce pain and reduce swelling. The area should be immobilized. Keep exertion to a minimum and obtain medical assistance as soon as possible. Antivenin is not readily available in the U.S.; treatment is for symptoms.

9. Natural Enemies:

Scorpions are preyed upon by several animals including birds, mammals, certain spiders and other scorpions.

III. SCORPION MANAGEMENT

1. **Population Monitoring Techniques:**

Scorpions may be monitored by carefully inspecting areas where they hide during the day. Folded clothes, sandy areas, crawl spaces and attics should be checked. Areas where water is available such kitchens and bathrooms should also be inspected. Many species of scorpion floresce under UV (ultraviolet) light at night. Use of a UV light indoors or out may be helpful in locating active animals.

2. **Threshold/ Action Population Level:**

Indoors or in heavily used outdoor areas, one scorpion should be the level at which control measures are set. In areas where scorpions are common, visitors should be informed and instructed on how to aviod being stung and what to do if stung.

3. **Management Alternatives - Nonchemical:**

The elimination of harborage such as wood piles and trash near structures will reduce local populations. Free water such as drips or puddles should be repaired or eliminated and toilets treated with a thin film of petroleum jelly on the lip of the bowl to prevent scorpions from climbing in. All drains should be plugged when not in use or screened to prevent access from the outside. All cracks and possible entrance holes should be caulked or plugged to prevent access to the structure. Shrubbery should be pruned back from buildings.

4. **Management Alternatives - Chemical:**

The following pesticides are recommended for use in NPS areas against scorpions (Schwartz, 1982):

- Silica aero-gel
- Allethrin.
- Chlorpyrifos
- Diazinon
- Malathion
- Pyrethrins

Pesticides should be applied to cracks and crevices and around window and door casings.

Dusts are preferred for treatment because they can be blown into wall voids and attics. Residual pesticides may be desirable because scorpions may remain in a structure for a long time. Sprays may be effective when applied to hiding places.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Repair all leaks and eliminate water sources.
2. Remove trash and other hiding places from around structures.
3. Treat with approved pesticide if necessary.

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V. BIOLOGY AND ECOLOGY OF SPIDERS

1. Species Described:

See page 21-22 of U.S. Department of Health, Education, and Welfare (1967), for pictorial keys to common groups and Ebeling (1975), for detailed descriptions.

Although spiders are common throughout the United States, only two; the black widows (several species) and the brown recluse are dangerous to humans. Most other spiders are shy and highly secretive, are sluggish, or rare, or possess fangs which are too small or weak to bite through human skin.

Tarantulas, though large and menacing looking, are rather sluggish and only bite after extreme provocation. Bites are usually not serious, resulting in mild pain lasting up to 1/2 hour, with little or no swelling or inflamation.

Brown spiders related to the brown recluse (genus Loxosceles) have been known to bite but in most cases the results are not serious. An exception, the South American brown spider (L. leata), has been reported from California and Massachusetts. It is similar in appearance to the brown recluse and symtoms of its bite are similar (Ebeling, 1975).

A. Brown widow - Latrodectus geometricus Koch

B. Red widow - L. bishopi Kaston

C. Common black widow - L. mactans (Fab.)

D. Northern widow - L. variolus Walckenaer

E. Western widow - L. hesperous Chamberlin and Ivie

F. Brown recluse (violin spider) - Loxosceles reclusa Gertsch and Mulaik

2. Geographic Distribution:

Widow spiders of the genus Latrodectus are found in all states and southern Canada. They are frequently found in railroad cars and trucks and have spread worldwide.

A. Brown widow - South Florida.

B. Red widow - South Florida.

C. Common black widow - Southern United States to Southern New England.

D. Northern widow - Mid-Atlantic States to Canada (widely overlaps range of common black widow).

E. Western widow - United States and Canada west of the Rockies.

F. Brown recluse (violin spider) - Permanent range is Texas, Oklahoma, Kansas, Missouri, Illinois, Kentucky, Tennessee, Alabama, Louisiana, and Mississippi. Reported from New York, California, Pennsylvania, New Jersey, Florida, North Carolina, Wyoming, and Washington, D.C. but not believed to perisit outside of normal range (Snetsinger, 1982).

3. Habitat:

Black widow spiders commonly live outdoors under and among objects such as stones, pieces of wood, hollow stumps, rodent burrows, among the leaves of plants, or in low shrubbery.

Black widows are most frequently encountered by humans indoors in dry and sheltered locations such as privies, barns, poultry houses, garages and cellars. Woodpiles and trash heaps are also favored sites. Different species prefer different habitats; the brown widow seems to prefer structures while the northern widow prefers outdoor shelter in trash piles or under stones.

The brown recluse is found outdoors under objects or other sheltered places in its southern range. In northern portions of its range, it is found only indoors, it is found in undisturbed areas of any room, especially unused bedrooms, closets, cellars, and garages. It is often found hiding in unused clothes or old shoes.

4. Hosts:

All spiders are predators feeding upon insects and other arthropods. Spiders inject venom into their prey to subdue it, followed by injection of predigestive fluid to digest and liquefy the internal organs of the prey. Feeding is by ingesting the fluids. Spiders can go for some time without feeding; brown spiders (related to the brown recluse) have been kept for over 2 years without food. Black widows have survived over 3 months without food.

Spiders capture prey through a variety of methods, the most familiar of which is the web. Black widows and the brown recluse are web building spiders.

5. Life Cycles:

Black widows - Eggs are deposited in special silken sacs which are constructed by the female. The number of eggs per sac is usually 300-400 and a female may construct 4-9 sacs during a summer. The female guards the egg sacs and moves them if necessary to repair her web. Eggs hatch in 8-10 days and the spiderlings remain in the sac for 2-4 weeks after hatching. They molt once within the sac. Spiderlings remain near the sac for several days and then disperse by spinning silken threads and ballooning away on air currents. Spiderlings are heavily preyed upon by other spiders including other widows however females will not eat their own young. Spiderlings are protected somewhat by being toxic to vertebrates if eaten.

Spiderlings may pass through up to 9 instars but well fed individuals mature in as few as 4-7 instars over 2-6 months. Immature instars vary in appearance from other instars and from adults. Most widows overwinter as immature forms, maturing in May or June, and begin to die in large numbers by late July. Widows have been kept alive under laboratory conditions for up to 2 years.

The web of the black widow is an irregular mesh of threads in which the female hangs upside down. There is usually a small central pocket where the spider retreats when threatened. Webs are about one foot square. Widows living under stones outdoors may spin smaller webs or none at all.

Contrary to popular belief, the female does not normally devour the male after mating Males live longer when associated with females due to her sharing of prey captured in the female web.

Brown recluse - The female spins a white egg sac, convex above and flat beneath. Up to 40 spiderlings may emerge from a single egg sac and the female may construct 1-5 sacs in a summer. Only about half of the eggs produce spiderlings; the rest are infertile or eaten by the female or older spiderlings.

Brown recluse spiderlings pass through 8 instars to maturity. The time required to reach maturity may take 8-14 months depending on available food and ambient temperatures. Females may live up to 4 years, males slightly less.

In the southern United States, mating occurs from February to October with June to July the most active period. Egg sac construction and oviposition occurs from February to September. Adult females are relatively sedentary in their webs; males and young disperse widely.

The web of the brown recluse is an irregular maze of silk without a pattern. It is constructed in undisturbed areas, and is often not recognized.

6. Seasonal Abundance:

Most spiders, including widows and the brown recluse, are most common in spring and early summer when spiderlings emerge and disperse.

Spiders are most hungry and aggressive and therefore most likely to bite after they have constructed egg sacs and oviposited. Widows will attack any object that touches the web.

7. Response to Environmental Factors:

In warm regions, populations of spiders are fairly constant from one year to the next. In northern areas, sporadic outbreaks of widows occur, followed by years of comparative rarity. Overwintering populations are reduced by periods of warm weather followed by cold snaps in late winter and early spring.

Populations indoors in heated areas are regulated only by availability of food and living space.

8. Medical Importance:

All reported cases of spider bite should be referred promptly to a physician:

Black widows - Children, elderly persons and persons with chronic diseases such as heart or respiratory disease are most seriously affected by bites from widows.

Bites are generally not always felt but there usually is some slight swelling and redness, with 2 red spots which mark the penetration of fangs. Pain from the bite increases for up to 3 hours and gradually subsides in 12-48 hours. In severe cases, muscle rigidity and spasms may develop and the muscles in the abdomen may become extremely rigid. Nausea, fever, elevated blood pressure, and profuse perspiration are all common symptoms.

Brown recluse spiders - Brown recluse spiders prefer to flee if possible and will only bite after provocation. Most bites occur to individuals

putting on old clothes or shoes which have not been worn for some time or by rolling on the spider in a long unused bed.

Typical symptoms of brown recluse spider bite include a stinging sensation followed by intense pain. Pain may occur immediately after the bite or up to several hours. A small blister forms at the bite, surrounded by sore tissue. The tissue killed by the venom sloughs off sometimes exposing underlying muscle tissue. Healing may take 6-8 weeks resulting in a sunken scar ranging in size from a penny to a half dollar depending on the amount of venom injected, and the sensitivity of the victim. Secondary infection frequently occurs during the healing process. The bite is rarely fatal. Treatment should begin within 48 hours of the bite to have any effect.

9. Natural Enemies:

Spiders are preyed on by a great variety of animals including insects, reptiles, birds, and some mammals, as well as scorpions and other spiders.

Black widows are preyed on by a related species (Steatoda grossa) which may occur indoors, by pirate spiders (Mimetus sp.), and by the blue burglar wasp (Chalylion californicum), which provisions its nest exclusively with widows as food for developing larvae. Eggs are preyed on by a fly (Pseudogaurax signatus) and parasitized by several parasitic wasps.

Little is known about the predators and parasites of the brown recluse, but cannabalism is common among young and adults.

VI. SPIDER MANAGEMENT

1. Population Monitoring Techniques:

Spiders are best monitored by visual search.

Webs are commonly constructed indoors in undisturbed places such as crawl spaces, cellars, and other sheltered, dry locations. Old unused webs are dusty and torn. Webs with fresh egg sacs are occupied.

2. Threshold/ Action Population Level:

Most species of spiders are considered beneficial in that they consume large quantities of insects. Tolerance levels for these spiders may be quite high in most park situations.

Widows and the brown recluse, due to their potentially dangerous bites, should not be tolerated in areas where they may encounter humans. The threshold level for these species is one spider or active web.

3. Management Alternatives - Nonchemical:

Spiders feed almost exclusively on invertebrates. Measure taken to reduce insect populations will also reduce the number of spiders preying on them. Tightly fitting screens on doors and windows will exclude adult spiders (newly hatched spiderlings can pass between screen mesh). Firewood, plants, and other objects brought into structures should be inspected first. All rubble, scrap, and lumber should be removed from buildings and away from exterior walls. Webs and egg cases can be destroyed by vacuuming and discarding or burning the bag.

In areas where widows or the brown recluse are common, follow the same precautions that would normally help prevent against scorpion stings.

4. Management Alternatives - Chemical:

The following pesticides are registered for use against spiders (Schwartz, 1982):

Silica aerogels
Chlorpyrifos
Diazinon
Malathion
Pyrethrins
Resmethrin

Indoors, a crack and crecice treatment is best.

Outdoors, dusts penetrate into wood or rubble piles where spiders spend such of their time. Silica aerogels may be used to treat attics, crawl spaces or wall voids.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. **Summary of Management Recommendations:**

1. Exclude spiders by use of screens and repair any holes which may allow entry.

2. Practice good sanitation by removing all rubble, scrap, and lumber piles from in and around buildings.

3. Vacuum to destroy webs and egg sacs.

4. Treat webs, cracks, crevices, and other areas with approved pesticides after the above actions have been carried out.

VII. BIBLIOGRAPHY FOR SPIDERS

A copy of the following articles may be obtained by contacting the IPM Coordinator, WASO.

Ebeling, W. 1975. Urban entomology. Univ. of California Press. Los Angeles. 695 pp.

Snetsinger, R. 1982. Spiders. In Mallis, A. (ed.). Handbook of pest control. Franzak & Foster, Cleveland, OH. 1101 pp.

Schwartz, P.H. 1982. Guidelines for the control of insect and mite pests of foods, fibers, feeds, ornamentals, livestock, and households. U.S. Department of Agriculture - Agricultural Research Service, Washington, D.C. USDA-ARS Handbook 584. 374 pp.

U.S. Department of Health, Education, and Welfare. 1967. Pictorial keys to arthropods, reptiles, birds, and mammals of public health significance. U.S. Department of Health, Education, and Welfare, Washington, D.C. 192 pp.

NATIONAL PARK SERVICE
IPM Information Package

STRUCTURAL PESTS I: TERMITES

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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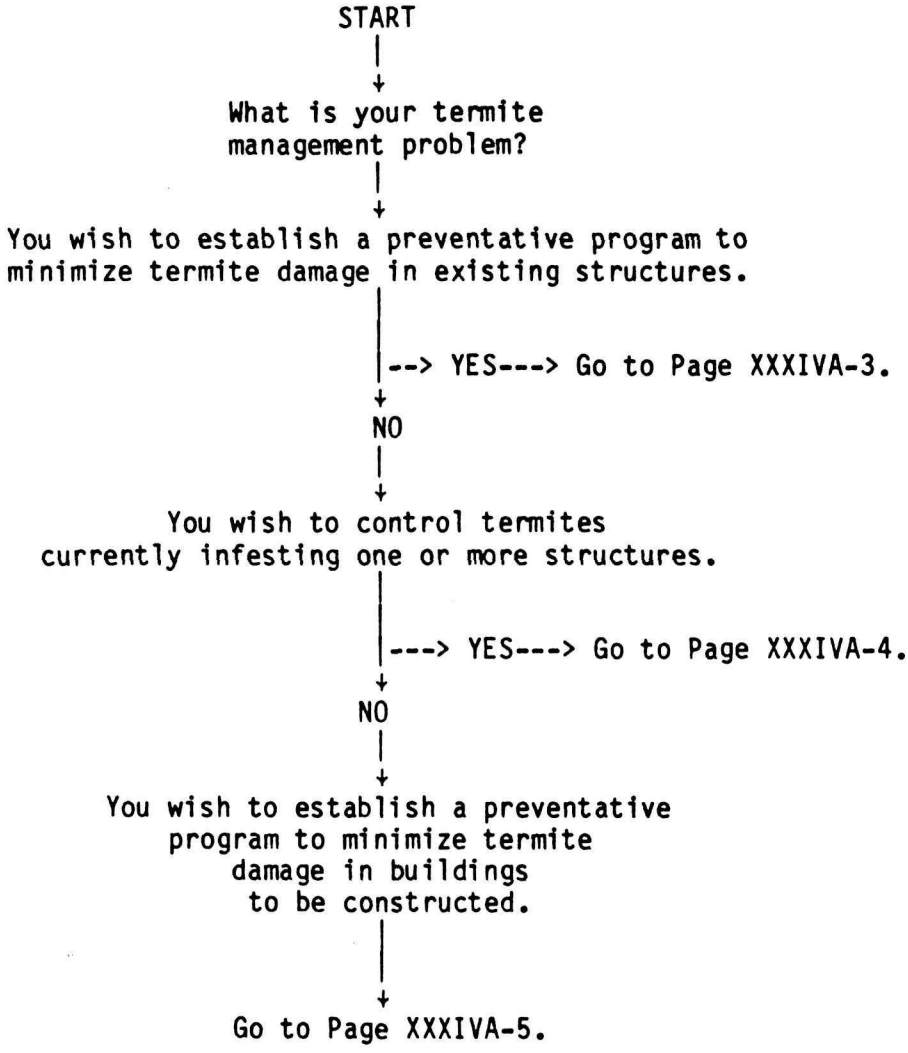
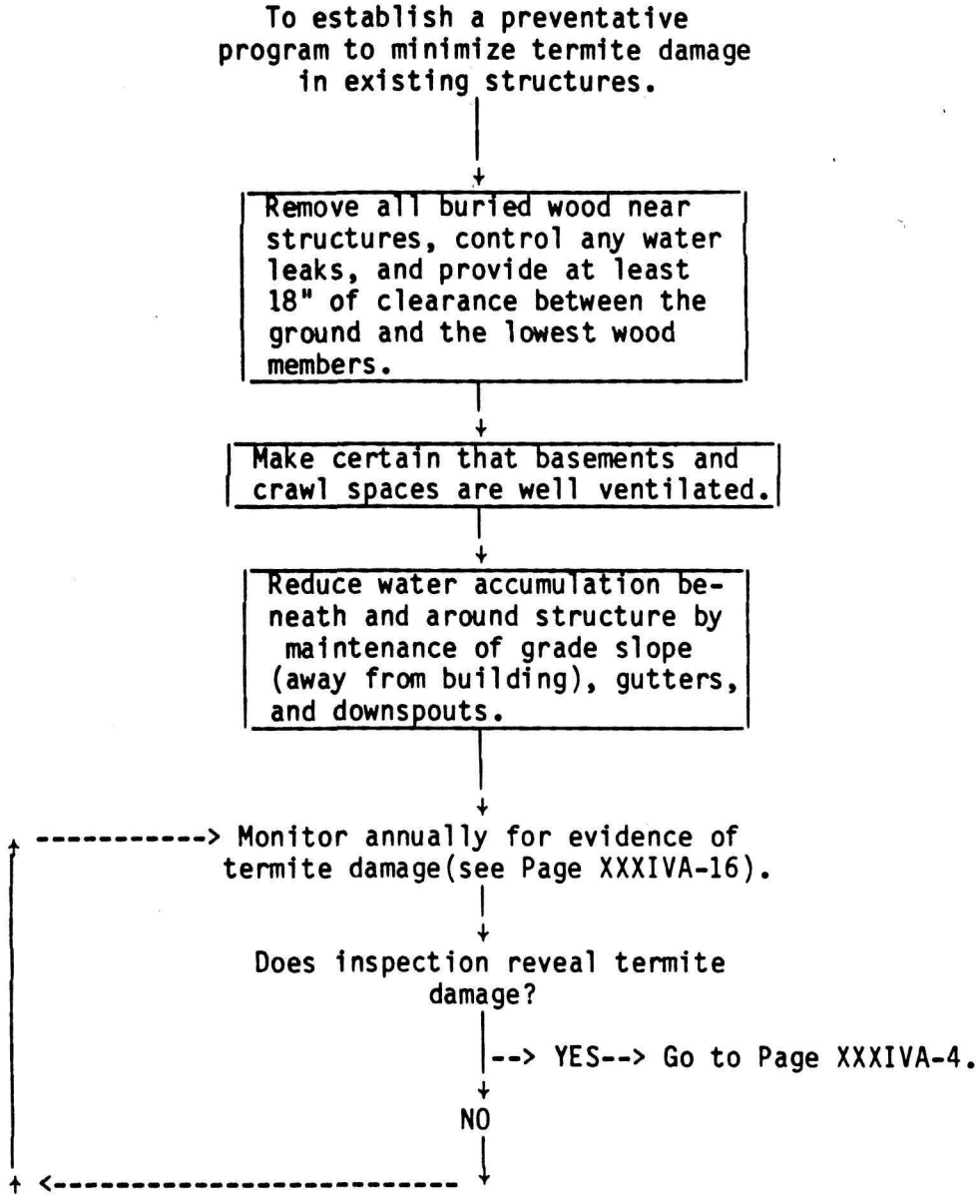
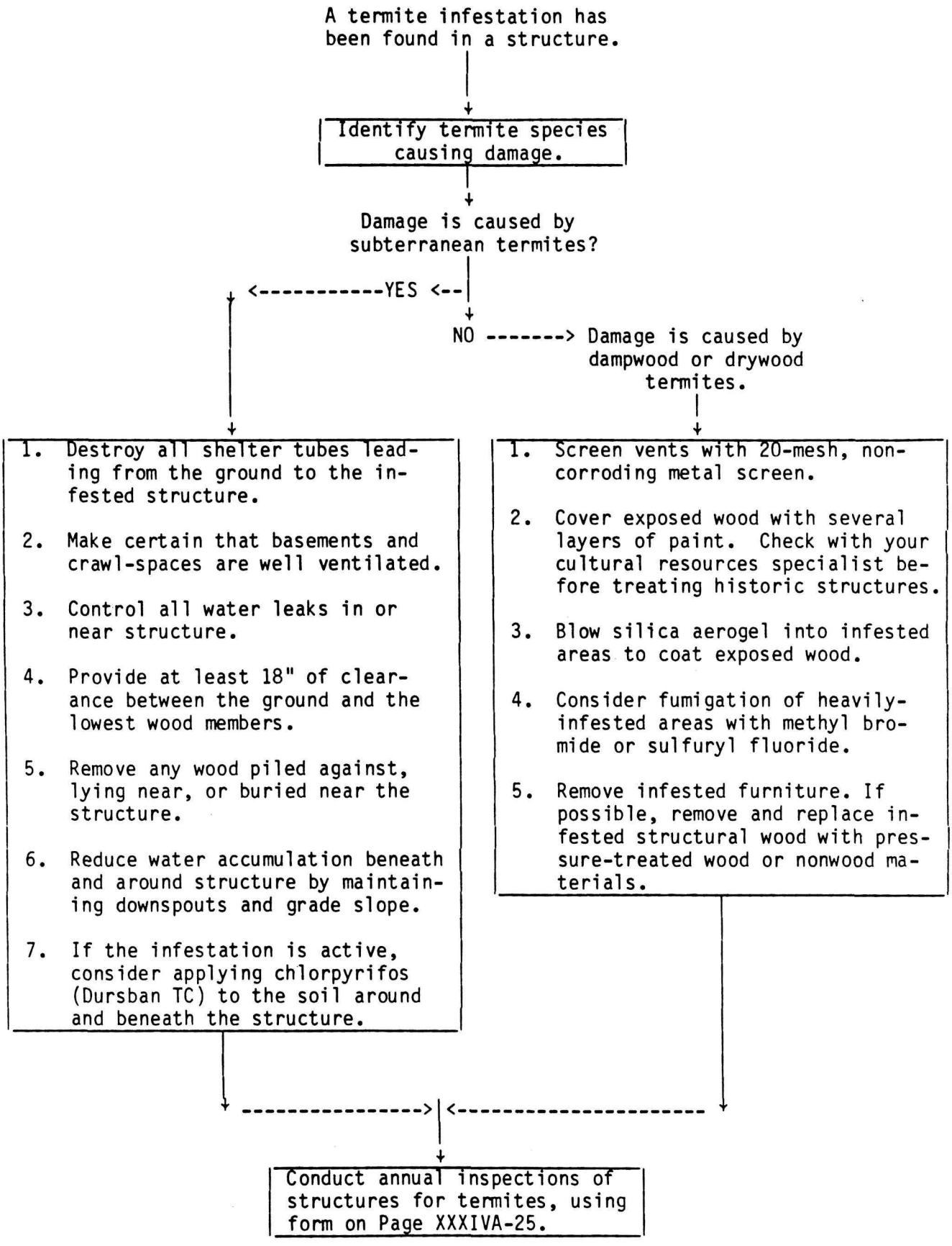
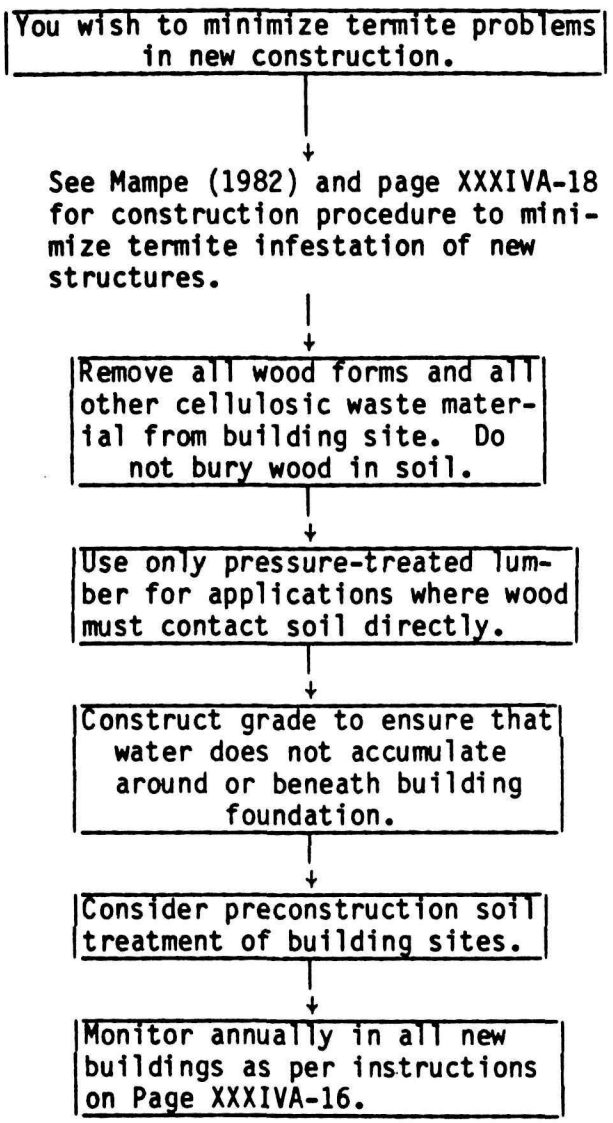
I. TERMITE IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




To establish a preventative program to minimize termite damage in existing structures.
Remove all buried wood near structures, control any water leaks, and provide at least 18" of clearance between the ground and the lowest wood members.
Make certain that basements and crawl spaces are well ventilated.
Reduce water accumulation beneath and around structure by maintenance of grade slope (away from building), gutters, and downspouts.
Monitor annually for evidence of termite damage(see Page XXXIVA-16).
Does inspection reveal termite damage?
--> YES--> Go to Page XXXIVA-4.
NO


A termite infestation has been found in a structure.
Identify termite species causing damage.
Damage is caused by subterranean termites?
YES
NO
Damage is caused by dampwood or drywood termites.
1. Destroy all shelter tubes leading from the ground to the infested structure.
2. Make certain that basements and crawl-spaces are well ventilated.
3. Control all water leaks in or near structure.
4. Provide at least 18" of clearance between the ground and the lowest wood members.
5. Remove any wood piled against, lying near, or buried near the structure.
6. Reduce water accumulation beneath and around structure by maintaining downspouts and grade slope.
7. If the infestation is active, consider applying chlorpyrifos (Dursban TC) to the soil around and beneath the structure.
1. Screen vents with 20-mesh, noncorroding metal screen.
2. Cover exposed wood with several layers of paint. Check with your cultural resources specialist before treating historic structures.
3. Blow silica aerogel into infested areas to coat exposed wood.
4. Consider fumigation of heavily-infested areas with methyl bromide or sulfuryl fluoride.
5. Remove infested furniture. If possible, remove and replace infested structural wood with pressure-treated wood or nonwood materials.
Conduct annual inspections of structures for termites, using form on Page XXXIVA-25.


You wish to minimize termite problems in new construction.
See Mampe (1982) and page XXXIVA-18 for construction procedure to minimize termite infestation of new structures.
Remove all wood forms and all other cellulosic waste material from building site. Do not bury wood in soil.
Use only pressure-treated lumber for applications where wood must contact soil directly.
Construct grade to ensure that water does not accumulate around or beneath building foundation.
Consider preconstruction soil treatment of building sites.
Monitor annually in all new buildings as per instructions on Page XXXIVA-16.

II. BIOLOGY AND ECOLOGY OF TERMITES

1. Species Described:

Between 45 and 50 species of termites are native to the United States (Mampe, 1982). While these insects are among the most beneficial in their natural habitat due to their consumption and removal of cellulose (in the form of fallen or moribund trees and other plants), this diet makes them among the most destructive insects to structures, furnishings, and commerce. A complete description of the life history and social structure of these pests is beyond the scope of this information package: reviews by Mampe (1982), Ebeling (1975), and Moore (1979) should be consulted for more information.

Termites can be grouped into soil-inhabiting (subterranean) and wood-inhabiting species. The second group includes drywood and dampwood termites. The major characteristics of these groups are described below.

Subterranean termites are relatively small insects which nest in moist soil, or in cellulosic material in contact with the ground. They characteristically produce tubes (made of sand or soil particles cemented together with fecal materials and adhesive secretions) which connect their in-ground colonies with colonized wood or other above-ground food materials. These tubes allow the termites to travel from the relatively dry above-ground wood to the moist soil colony periodically to replace lost body moisture. The tubes serve to isolate the termites from drying wind and sunlight, as well as from natural enemies. When winged reproductive forms (alates) leave the colony to mate, they do so through swarming tubes, which may extend from 4 to 8 inches above ground level. Subterranean termites do the most damage to structural wood of any termite type. The following species are described in detail:

A. The Eastern subterranean termite (Reticulotermes flavipes Kollar) includes three distinct morphologic forms (castes). Alates (winged reproductive forms) are about 1/5" long, black in color with four white opaque wings of equal length. Soldiers are about 1/4" long, pale in color, with enlarged, dark heads bearing very large mandibles. Workers are less than 1/5" long, and are pale to white in color. Alates (referred to as kings and queens) are the only reproductive forms. Soldiers are responsible for defending the colony against enemies. Workers tend and feed the other forms,

care for the eggs laid by the queen, and do the work of extending the colony and building shelter tubes.

B. The Western subterranean termite (R. hesperus Banks) resembles R. flavipes in form and caste structure.

C. The Formosan termite (Coptotermes formosanus Shiraki) also includes three castes. Alates have yellow-brown bodies about 1/2 inch in length and are larger and lighter in color than alates of native species. Wings are 2/5" long, and have many hairs. Soldiers usually make up 10-25% of a colony (compared to 2-3% in other subterranean species). They can be identified by their enlarged, rounded heads. Each soldier bears a forward-facing opening (fontanelle) in the front of the head, which can release a sticky, acidic secretion used in colony defense. Workers are pale, and resemble the workers of other subterranean species. All forms are larger than those of native species.

Wood-inhabiting termites do not colonize soil, but live entirely within infested wood. They are much less common than the subterranean species. The two major groups of wood-inhabiting termites found in the United States are;

Drywood termites (Kalotermes, Incisitermes, and Cryptotermes spp.), which live within relatively dry, nondecayed wood, and do not require contact with soil. Their colonies are generally smaller than those of subterranean termites, and may occur in furniture, wood boxes, and dead tree limbs. Drywood termites characteristically produce solid fecal pellets which may be heavily sculptured in appearance, and which can often be found in sawdust-like piles near kick-out holes in infested wood. Cryptotermes spp. are the most common wood-inhabiting termites. They attack furniture, woodwork, and floors. These termites require very little moisture, do not require ground contact, and appear to be spread by movement of infested wood.

D. The Western drywood termite (Incisitermes minor) produces no worker caste. The work of the colony is performed by juveniles (nymphs), which grow into alates or soldiers. I. minor alates are nearly 1/2" long, and are dark brown with red-brown heads and thoraxes, and smoky-black

wings. Soldiers are similar in size, wingless, pale in color, with enlarged, pigmented heads with enlarged mandibles.

E. Alates of the common drywood termite (Cryptotermes brevis Walker) are brown, 3/8" long with colorless wings bearing brown veins. Soldiers are about the same length as alates, with broad, high, concave, black heads. The work of the colony is performed by pale nymphs.

Dampwood termites (Zootermopsis spp.) are larger than other types, and require more moisture; therefore, their colonies are usually found in damp or decaying wood or logs. No connection with the soil is required for these species. As in the drywood termites, no worker caste is produced. The feces of these species are large, oval pellets.

F. Alates of the Pacific dampwood termite (Z. angusticollis Hagen) are up to 1" long, yellow-brown or brown in color, with dark brown wings. Soldiers are up to 3/4" long; the elongated head is black, while the thorax and abdomen are a light reddish-brown. The mandibles of these forms are long and toothed. Nymphs are cream-colored to white, and about 1/8-1/2" long. They perform the work of the colony, and mature into reproductives or soldiers. Eggs are about 1/10" long, white, and beanshaped. Liquid feces are produced, along with roughly hexagonal pellets about 1/2" long.

In addition to the species noted above, numerous other subterranean, dampwood, and drywood termites occur in various regions of the U.S. The examples noted are included as being representative of their groups. Consult your U.S. Department of Agriculture Cooperative Extension Service representative or state university entomologist for details on species occuring in your area.

2. Geographic Distribution:

A. Eastern Subterranean Termite - Occurs throughout the United States east of the 100th meridian (e.g., mid-Kansas) where average minimum winter temperatures do not fall below -20°F.

B. Western Subterranean Termite - Occurs throughout the Pacific Coast from British Columbia to Baja California, and east into Idaho and Nevada.

C. Formosan Termite - This species is native to Formosa, Japan, and China, and was probably introduced into the U.S. with military supplies after World War II. Infestations have been recorded in Hawaii, Texas, Louisiana, South Carolina, California, and Florida.

D. Western Drywood Termite - Occurs in California and Arizona; also in the Carribean zone. Isolated infestations may occur elsewhere, due to spread in infested lumber.

E. Common Drywood Termite - Natural range includes most tropical and subtropical regions of the earth. It is believed that C. brevis was introduced into the U.S. on shipments of infested lumber. Its U.S. range includes Florida, Louisiana, and Hawaii, but it is transported to all states in infested wood.

F. Pacific Dampwood Termite - Occurs throughout the Pacific Coast, from British Columbia to Baja California.

3. Habitat:

A. Eastern Subterranean Termite - Lives in soil, or in wood or other cellulosic material contacting soil. Inhabits above-ground wood if connections to soil are maintained through closed earth and cellulose shelter tubes. May on occation colonize permanently moist wood (Ebeling, 1975).

B. Western Subterranean Termite - Similar to A. in habitat preference, but prefers cool, moist, shady locations.

C. Formosan Termite - Lives in wood, several species of living trees, stumps, poles, and buried wood debris. Nests may be independent of soil if another source of water is available.

D. Western Drywood Termite - Lives in nondecayed wood with low moisture content. Substrates include lumber and trees.

E. Common Drywood Termite - This species has not been reported from any natural habitat within the U.S. It apparently only occurs in buildings in the U.S.

F. Pacific Dampwood Termite - Found in wood of fallen conifers in cold and humid areas, in beach areas with high water tables, coastal forests, and in areas where wood is kept moist by irrigation water.

4. Hosts:

A. Eastern Subterranean Termite - Most wood, except juniper, teak, and redwood (heartwood).

B. Western Subterranean Termite - See 4.A.

C. Formosan Termite - Most wood.

D. Western Drywood Termite - Hosts include English walnut, eucalyptus, Citrus spp., apricot, avocado, alder, almond, cherry, California laurel, Monterey cyprus, oak, peach, pear, sycamore, plum, willow, and other ornamentals. Termites enter trees through injuries.

E. Common Drywood Termite - No natural hosts known in U.S.

F. Pacific Dampwood Termite - Pacific coniferous trees and shrubs.

5. Life Cycles:

A. Eastern Subterranean Termite - Alates swarm in January to August, depending on location. Termites are not good fliers, and usually do not spread more than 200 yards from their swarm tubes before landing, shedding their wings, and pairing off. Each new pair seeks a dark cavity in nearby soil or ground-level wood, excavates the cavity, and mates within a day after swarming. Mated pairs remain together until death.

Growth of a colony from a primary pair may be slow. As few as 12-15 eggs are laid during the first year. The eggs hatch in about a month. Young nymphs resemble miniature adults during their first two instars, each of which may last up to a month. By the third instar, future reproductives can be differentiated from future workers and soldiers. Workers and soldiers mature in about 1 year, while reproductives may require 2 years. A functional colony may contain as many as 100,000 individuals. In addition to a primary king and queen, secondary reproductives (with wing buds) may be present in large numbers (up to several hundred). These also contribute eggs to the colony and can take over the functions of the primary pair should they die. The life span of an individual termite may be as long as 5 years. Such longevity, combined with their cryptobiotic ("hidden") lifestyle, constant reproduction, and permanent food supply, make termite colonies long-lived.

Newly-hatched nymphs do not contain the intestinal flora needed for wood feeding. They obtain it during the first instar by fecal feeding and by feeding on the abdominal secretions of workers.

B. Western Subterranean Termite - The life cycle of this species is similar to that of the Eastern subterranean termite (R. flavipes). Alates swarm in the fall and winter, especially after rain. Sporadic flights may occur during the winter or spring if the weather is dry. Colony formation varies from that of R. flavipes in that the Western termite queen lives in a large, special chamber with the king and a number of soldiers. Periodically, the queen and her entourage will move to another chamber of similar size.

C. Formosan Termite - Alates swarm from March through July in the U.S., and in spring and fall in Hawaii. In Louisiana, alates fly between dusk and midnight (Jones and La Fage, 1980). After flying briefly, the reproductives pair off and search for a suitable nesting site in wood or the soil. When a site is located, the insects construct a small chamber in which mating occurs. The queen begins laying eggs about 5-15 days after the mating chamber is built. One to four eggs are produced each day, until about 30 are laid. The eggs hatch in 24-32 days. About 10% develop into soldiers, while the rest become workers; this ratio is maintained during the first few years of colony growth. No more eggs are produced until after the first brood hatches. Mature queens may lay up to 1000 eggs per day. Colony development is slow; a two year old nest may contain only 250 insects. Third year colonies may contain 1,250, and fourth-year colonies may contain 50,000. The age of a colony when the first alates are produced is not known, but is believed to be greater than 5 years (Jones and La Fage, 1980). Old colonies (over 15 years) may contain millions of individuals.

D. Western Drywood Termite - Alates swarm from June to December depending on location. They may travel up to a mile in wind currents before dropping to the ground, shedding their wings, pairing off, mating, and searching for a site to begin a colony. Once a pair excavates a cavity, they seal themselves in, and the queen lays 2-5 eggs during the first year. Nymphs obtain their intestinal flora from secretions of the adults and begin expanding the colony. Each year, from late spring to late fall, the queen lays 1-12 eggs per day for 7-10 days, rests for about 30

days, and repeats the egg-laying cycle. By the end of the second year, the colony may contain up to 40 termites; by the end of the fifteenth year, there may be as many as 2,600. The first alates are released after about 4 years.

Alates and soldiers require about 1 year to mature. Alates develop after 7 nymphal instars; soldiers require 4-7. Queens reach their maximum egg laying rate at about 10-12 years of age, after which the rate decreases and another female takes over as the primary queen.

E. Common Drywood Termite - Similar to 5.D., but swarming occurs in May or June.

F. Pacific Dampwood Termite - Alates swarm mainly from August to October. Females excavate openings in wet or decaying wood, which are later entered by males. The opening is then sealed with wood pellets and feces, and the pair mate within two weeks of flying. Within 14-18 days after mating, the female lays between 6 and 22 eggs. A second clutch is laid the following spring. Supplementary reproductives contribute additional eggs, so that a colony may eventually have 4,000 individuals.

6. Seasonal Abundance:

A. Eastern Subterranean Termite - Swarming usually occurs in mid- to late spring, although flights may occur as early as January or (rarely) as late as July or August. Swarms produced during the early part of the year are usually larger than later swarms. Outdoor colonies must move below the frostline during cold weather.

B. Western Subterranean Termite - Swarming may occur from early autumn through winter, and (rarely) as late as May or June. The largest swarms occur in the fall, especially on sunny days following rain. In dry years, emergence may be delayed until the soil has been softened by winter or spring rains so that nests can be established.

C. Formosan Termite - Swarming occurs from March through July in the southern U.S., peaking in May and June in Louisiana. Spring and fall swarming occur in Hawaii.

D. Western Drywood Termite - Alates swarm during sunny days in early summer to late fall.

E. Common Drywood Termite - Swarming takes place in May or June in the United States.

F. Pacific Dampwood Termite - Swarming may take place throughout the year, but is most evident between August and October, especially after rain.

7. Responses to Environmental Factors:

A. Eastern Subterranean Termite - Alates are attracted to light; all other forms avoid light, possibly as a means of avoiding dry air. Colonies will move to lower chambers in response to cold surface temperatures. Individuals cannot survive in above ground wood without frequently traveling to the in-soil colony through shelter tubes to replenish lost body moisture. Blockage of access to the in-ground colony generally results in the death of individuals trapped above-ground.

B. Western Subterranean Termite - Alates are attracted to light, and generally swarm on sunny days. They will fly during cloudy weather, if the temperature is above 64°F (Light, 1934). Also see 7.A.

C. Formosan Termite - Alates are attracted to light. Bess (1970) has suggested that high humidity is required for colony initiation. Nests are constructed of "carton", a composite of feces, saliva, and digested wood which retains available water. If soil water is not available, Formosan termites will consume water that condenses on pipes or that collects in structural defects and rain gutters. This species often colonizes soil that is poor in cellulosic materials, and will extend foraging galleries up to 200 feet from the main nest.

D. Western Drywood Termite - Alates are attracted to light. Under very dry conditions, individuals will avoid dessication by sealing themselves within cavities in wood and huddling together to conserve moisture. One individual was reported to have survived for 245 days in a block of kiln-dried wood under dessication; when placed near water, the termite drank until turgid, then behaved normally (Ebeling, 1975).

E. Common Drywood Termite - No information was available.

F. Pacific Dampwood Termite - Alates are attracted to light. Swarming is most evident after rains.

8. Impact of Termites:

8.1 Direct Impact:

A. Eastern Subterranean Termite - This pest will destroy any cellulosic material, including lumber, paper, cotton, books, and dead tree roots. Noncellulosic materials (e.g., underground cables, cement) may be damaged by termites which chew through them in search of food.

B. Western Subterranean Termite - See 8.1.A.

C. Formosan Termite - See 8.1.A. These termites will consume wood that is resistant to attack by native termites, and can destroy wood up to six times faster than native species can. Soldiers can penetrate lead, asphalt, plaster, mortar, creosote, rubber,and plastics (by means of the acidic secretions of their fontanelles) to obtain underlying wood.

D. Western Drywood Termite - This species will damage dead trees, lumber, utility poles, wooden structural members in buildings, bridge and marine pilings, and redwood (which native subterranean termites usually do not attack).

E. Common Drywood Termite - Damages furniture, woodwork, and flooring, but can attack structural wood if infestations are allowed to proceed for many years.

F. Pacific Dampwood Termite - Causes most damage where ground-wood contact points exist (e.g., bridge timbers, foundation wood). Will work up from foundations to roof rafters.

8.2 Indirect Impact:

All termites can spread wood-rotting fungi while tunneling through infested wood. In addition, termite damage to wood flooring and foundations may reduce the structural soundness of the materials, which could lead to injury to personnel and visitors using the infested structure. Swarming alates may create nuisance situations, especially if flights occur inside infested structures.

9. Natural Enemies:

Natural enemies of termites include ants, birds, spiders, centipedes, amphibians, and small mammals. Except during swarming, termites are protected from their natural enemies within infested wood or in shelter tubes. Several species of fungi are known to infect termites; however, none has undergone field testing as a biocontrol agent. A nematode (Neoplectana carpocapsae) that carries a parasitic bacterium (Xenorhabdus nematophilus) is under development as a biologic termiticide (Weidner, 1983).

III. TERMITE MANAGEMENT

1. Population Monitoring Techniques: The most effective technique available for monitoring termite populations in or near buildings is an annual inspection for evidence of termite damage in wood. Signs of termite presence include:

A. Eastern Subterranean Termite -

1. Reports or observation of large numbers of alates in or near a structure. The alates may be the first evidence of infestation, and may be confused with flying ants. Termite alates have four wings of the same size, all nearly 2 times the body length. Ants have one pair of wings longer than the other, with the longest as long as the body. Termite alates are not "wasp-waisted", as are ants. Also, the antennae of ants are elbowed, while those of termites are not.

2. Dark areas or blisters in flooring or other wood framing. Such areas can easily be crushed with a sharp tool, revealing termite cavities and perhaps the insects themselves.

3. Termite-infested wood comes apart easily when probed with a screwdriver, revealing termite tunnels, frass or fecal deposits, and live termites, if the infestation is active.

4. Subterranean termite infestations are connected to the underground colony by earth and cellulose shelter tubes. The presence of such tubes on the surface of wood or other structural surfaces indicates that an infestation exists. The absence of such tubes, however, does not mean that termites are not present.

B. Western Subterranean Termite - See 1.A.

C. Formosan Termite - See 1.A. Also monitor for the following signs of infestation:

1. Reports of unusually large numbers of alates, and/or of unusually large proportions of soldiers.

2. Soldiers will swarm onto the hand of anyone probing an infested site with a finger (and will bite).

3. Formosan termite alates swarm after sunset, unlike those of native species, which are day fliers.

4. Evidence of termite activity may be found near sources of water, such as plumbing leaks or wood under roofs.

D. Western Drywood Termite:

1. The first evidence of drywood termite attack is usually the presence of piles of brownish fecal pellets below small holes (about 1/8" in diameter) or cracks in infested wood.

2. The flight of alates in or near a structure during warm, sunny autumn days indicates a nearby colony.

3. See 1.A.3. Infested wood may be filled with loose fecal pellets. Since drywood termites consume wood up to the paint, apparent paint blisters are formed. These break on slight pressure, releasing fecal pellets.

E. Common Drywood Termite - See 1.A.

F. Pacific Dampwood Termite - See 1.A.

A sample termite inspection report form is shown on Page XXXIVA-25. Similar forms should be made out for each building inspected, and retained for later reference. A key for identifying the signs and symptoms of termite damage can be found in Kaae and Young (1976).

2. Threshold/ Action Population Levels:

Since the damage caused by termites (especially subterranean and drywood species) can be so extensive, and the pests themselves may survive undetected until damaging levels are reached, the presence of an active infestation is the threshold level for termites. In natural areas, termites are beneficial, and should not be managed.

3. Management Alternatives-Nonchemical:

A. Eastern Subterranean Termite -

1. Prevention of wood-ground contact - Structural wood should not be less than 18" above the ground. Wood steps should be supported on a concrete base extending at least 6" above ground level, and should be separated from the main structure by a metal shield. Termites will build shelter tubes over the shield to reach wood; such tubes will be easily seen. Any shelter tubes found should be destroyed.

2. Removal of wood debris - All wood (stumps, scrap wood, wood chips, sawdust, or form boards) should be removed from beneath all structures. No wood should be buried in the fill near buildings.

3. Avoidance of excess moisture - Subterranean termites prefer moist soil; therefore, building sites must be graded to prevent accumulations of moisture around or under a structure. Downspouts should carry water away from the building. All plumbing leaks should be corrected. Vents should allow cross-ventilation and removal of moisture. Placing plastic sheets on the ground can keep moisture out of the structure.

4. Foundation protection - Building foundations should be of solid reinforced concrete, to prevent cracking. Where stone, brick, or masonry is used, it should have a metal shield or 4" concrete capping. Exterior foundation walls should extend at least 18" above the outside grade line. Where foundation walls are even with or lower than the outside grade, they should be raised to at least 4" above grade, or a concrete (1:3 Portland cement:sand) flash wall should be installed against the building, extending from 6" below the grade line to at least 6" above the grade line. This procedure cannot be performed on historic buildings.

5. Ground leveling - The ground beneath a building should be leveled, and should provide at least 18" of clear space between horizontal timbers and the ground (24-30" in humid parts of the U.S.).

6. Basement protection - Pressure-treated wood (see Page XXXIVA-20, 4.A.2) should be used in the basement of a structure, if the wood will touch the ground. No wood should extend into the foundation concrete, and all form pieces should be removed. Foundation or wall cracks should be sealed with noncorrosive metal expansion joints. Wooden partitions or stored materials

should be placed on concrete or shielded supports. Hatchways and windowframes should be made of concrete, metal, or pressure-treated wood.

7. Basement venting - In unfinished basements, vents should provide cross-ventilation. At least 2 square feet of air space per each 25 linear feet of foundation wall should be provided. Dead air pockets should be prevented. Vent frames must not be in contact with ground.

Detailed information on these and other related techniques can be found in Mampe (1982), Anon. (1971), Anon. (1977), and Moore (1979).

B. Western Subterranean Termite - See 3.A.

C. Formosan Termite - See 3.A.

D. Western Drywood Termite

1. Building protection - Infested wood should be removed and replaced with pressure treated lumber. Coating exposed wood with several layers of paint will inhibit termite activity (painting of historic structures may not be possible). Also, covering vents with 20-gauge mesh will prevent entry of termites. Attics should be screened to keep swarming alates out.

2. Stored lumber protection - Wood to be protected should be supported on piers made of concrete or pressure-treated wood. Debris should be removed from the storage area.

E. Common Drywood Termite - No information is available.

F. Pacific Dampwood termite

1. Moisture reduction - See 3.A.3.

4. Management Alternatives - Chemical:

A. Eastern Subterranean Termite

1. Soil treatment - The goal of soil treatment is the creation of a zone of poisonous soil between the structure to be protected and the termites. Soil treatment should be performed, prior to construction, by trained applicators (due to the complexity of the operations required and the toxicity of the chemicals used). Chlorpyrifos (Dursban TC) is the only pesticide currently recommended for soil application by the National Park Service.

2. Wood preservatives - Lumber directly exposed to termite attack should be treated with preservatives to inhibit infestation. Most lumber manufacturers use a pressure-treatment process to impregnate lumber with a registered preservative, such as chromated copper arsenate (CCA). Treated lumber should be used only where termite attack or fungal decay is likely. An additional benefit of the use of pressure-treated lumber is that, since termites will not consume it, they must tunnel over it, exposing their shelter tubes to view.

B. Western Subterranean Termite - See 4.A.

C. Formosan Termite - See 4.A. In addition, studies are being conducted to support labeling of methyl bromide, sulfuryl fluoride, and Vikane® for fumigation of secondary colonies.

D. Western Drywood Termite

1. Silica aerogel - Silica aerogel can be blown into attics and similar areas where active infestations are found. The dust coats exposed wood members, termite fecal pellets, and swarming alates, and is effective indefinitely under dry conditions.

2. Fumigation - Individual infested structures can be fumigated with methyl bromide to eliminate infestations. This procedure is hazardous, and should only be performed by certified applicators. Sulfuryl floride has also been used.

E. Common Drywood Termite -

1. Fumigation - Fumigation of infested wood with sulfuryl floride, chloropicrin, or methyl bromide

has been shown to be effective against these insects (Bess, 1971). Active colonies may be controlled by injection of chlorpyrifos solutions into galleries through kickout holes.

F. Pacific Dampwood Termite - No information is available.

5. Summary of Management Recommendations:

A. Eastern Subterranean Termite -

1. Inspect all structures for termite damage every year.

2. Remove all ground-wood contact points.

3. Use only wood which has been pressure-treated with a preservative (e.g., CCA) where wood will contact ground.

4. Maximize drainage and cross-ventilation under structures, and use other techniques to limit moisture in and around structural wood.

5. Use construction practices noted on Pages XXXIVA-18-19 to inhibit termite damage.

6. Remove all cellulosic debris (such as wood and paper) from soil in building area.

7. Where active infestations are found, treat soil around and under foundations with chlorpyrifos. Spot-treat sources of infestation, if possible.

B. Western Subterranean Termite - See 5.A.

C. Formosan Termite - See 5.A. Also repair or remove sources of water. Find and treat nearby colonies in wood, structures, or soil.

D. Western Drywood Termite -

1. Cover all entry points (windows, vents, louvers, eaves, etc.) with 20 mesh noncorrosive metal screening, to prevent termite entry into structure.

2. Maintain smooth exterior building surfaces; fill all cracks and joints before painting. A heavy layer of paint on exterior wood will inhibit infestation.

3. Replace infested wood with pressure-treated lumber, or inject approved termiticides into active termite nests.

4. Treat attics and similar spaces with silica aerogels if active infestations are found.

5. Fumigate heavily-infested structures with a registered fumigant.

E. Common Drywood Termites - See 5.D.

F. Pacific Dampwood Termite - See 5.D.

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V. SAMPLE TERMITE INSPECTION REPORT FORM (SIDE 1.)

Building Name or Number _____

Building Address or Location _____

Person to Contact _____ Phone _____

Survey Date _____ Inspector _____

Building Data (Check One):

1. TYPE OF STRUCTURE
   basement___ slab___
   crawl___ combination___

2. FOUNDATION
   concrete___ hollow block or tile___
   stone___ multiple brick___
   brick veneer___ single brick___
   piers only___ combination___

3. EXTERIOR
   wood___ hollow block___
   stone___ stucco on frame___
   brick___ stucco on masonry___

4. PORCHES
   wood___ dirt filled___
   masonry___ hollow___
   type flooring on masonry___

5. BASEMENT
   ceiling finished___with_____
   walls finished___with_____
   floor finished___with_____
   venting sufficient?___
   vents screened?___

6. SLAB
   supported___ floating___
   monolithic___ wood over slab___
   floor covered___with_____
   plumbing accessible?___
   heating accessible?___
   type of heat_____
   blue prints available?___

7. GENERAL INFORMATION
   paving against foundation___feet
   planters___ shrubs, plants___
   soil type_____
   clearance in crawl space___inches
   are all areas accessible?___
   must openings be made?___
   are wood supports in contact with ground or embedded in slab?___
   are form boards present?___
   buried wood waste present?___
   accumulations of water present?___
   plumbing leaks present?___
   is grade correct?___
   wells or other special precautions?___

Inspection Data:

1. INFESTATION FOUND
   termites?___ species_____ is infestation active?___
   other insects?___ species_____
   wood decay fungi?___

2. LOCATION, INTENSITY OF INFESTATION
   Describe fully, showing locations on building diagram on reverse side of this sheet.

SAMPLE TERMITE INSPECTION REPORT FORM (SIDE 2.)

3. TREATMENT/REPAIR RECOMMENDATIONS

4. DATE OF TREATMENT_____
   DATE OF REPAIR_____

5. REMARKS:

6. BUILDING DIAGRAM: show infestations, needed repairs, and nearby sources of termites.

INSTRUCTIONS FOR TERMITE INSPECTION

When inspecting a structure for termite damage, the following procedures should be carried out:

- Inside and outside walls should be carefully examined for termite shelter tubes, especially near soil, in basements, and in crawl spaces.

- Exposed wood (e.g., floor joists, sills, roof trusses) should be tapped with a tool, to indicate (by difference in sound) whether the wood has been damaged internally. Probe suspicious areas with a screwdriver. Infested wood comes apart easily, revealing termite tunnels, frass deposits, fecal pellets, and/or the termites themselves. Wood showing paint blistering, and flooring showing blistering or isolated stained areas, should also be probed.

- Wood paneling and other wall finishings on basement walls, wood partitions, and other basement wood which extends from masonry to sills or joists should be examined.

- Plumbing and utility fixture passages through the basement floor or foundation should be checked.

- Stone, concrete, cinder block, hollow tile or brick walls should be examined for cracks or holes through which termites could enter.

- Unscreened openings should be noted.

- Signs of termites, such as shed wings, dead individuals, or piles of fecal pellets should be noted.

- Signs of buried wood near or under the building should be noted, and exposed debris should be examined for termite damage.

- The results of each inspection should be recorded on a form, and retained for future reference. A drawing of each building inspected should be made on the reverse side of the form used for that building, detailing a) sites of observed infestations, and b) structural or other repairs necessary to maintain structure so as to prevent new infestations.

NATIONAL PARK SERVICE
IPM Information Package

STRUCTURAL PESTS II: CARPENTER ANTS, CARPENTER BEES, OLD HOUSE BORERS, POWDERPOST BEETLES, FLATHEADED BORERS

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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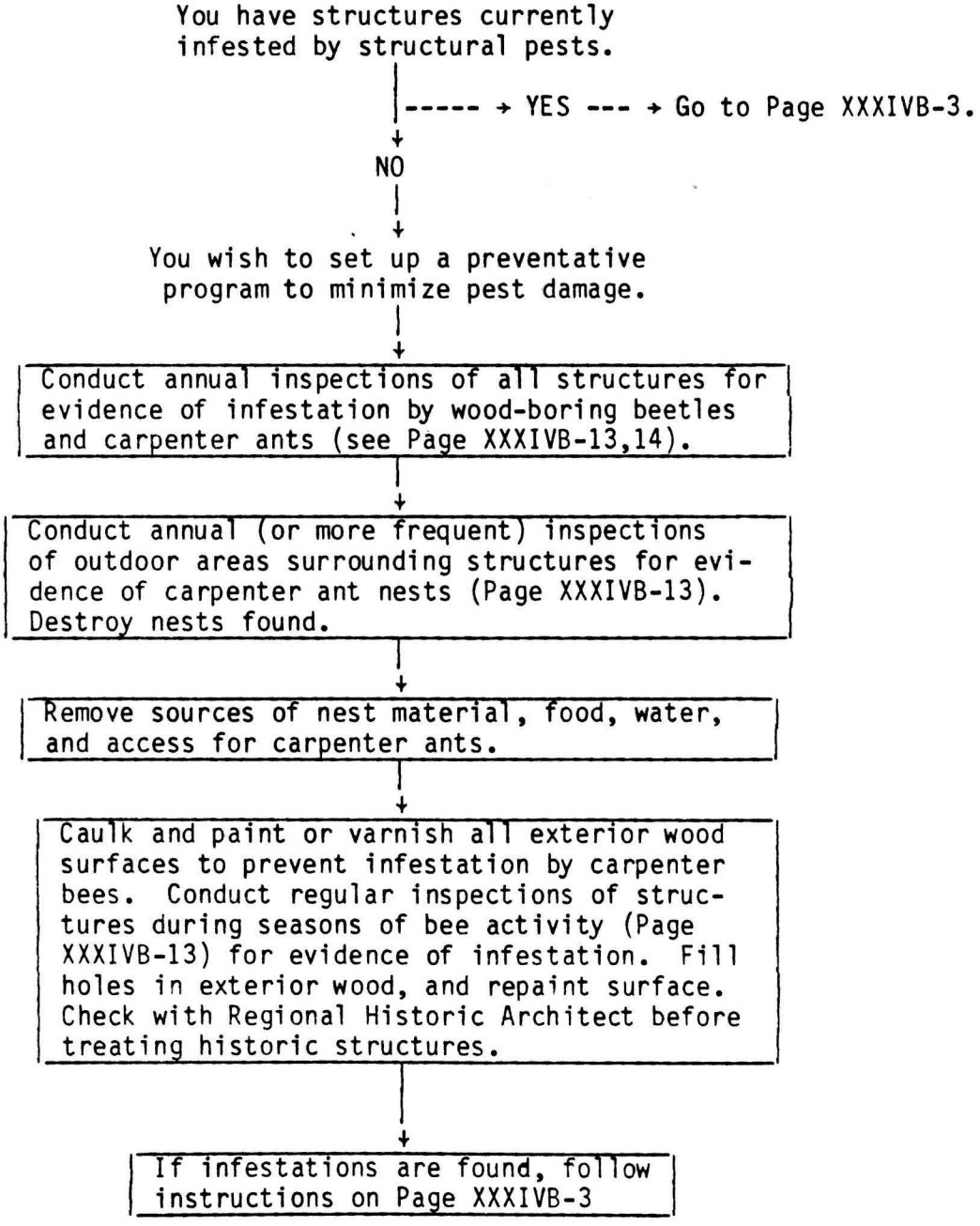
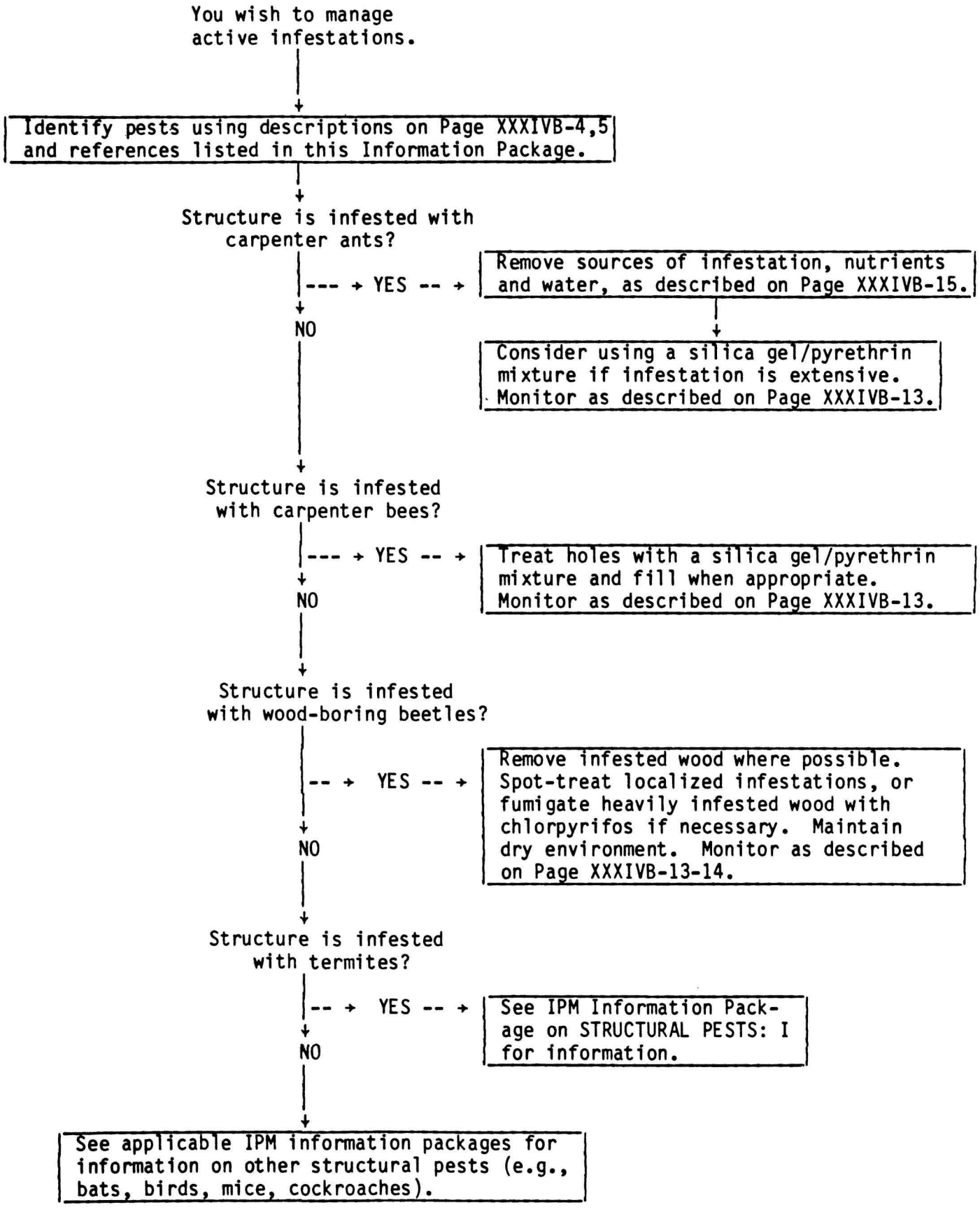
I. STRUCTURAL PEST IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




You wish to manage active infestations.
Identify pests using descriptions on Page XXXIVB-4,5 and references listed in this Information Package.
Structure is infested with carpenter ants?
--- → YES -- →
Remove sources of infestation, nutrients and water, as described on Page XXXIVB-15.
Consider using a silica gel/pyrethrin mixture if infestation is extensive. Monitor as described on Page XXXIVB-13.
NO
Structure is infested with carpenter bees?
--- → YES -- →
Treat holes with a silica gel/pyrethrin mixture and fill when appropriate. Monitor as described on Page XXXIVB-13.
NO
Structure is infested with wood-boring beetles?
-- → YES -- →
Remove infested wood where possible. Spot-treat localized infestations, or fumigate heavily infested wood with chlorpyrifos if necessary. Maintain dry environment. Monitor as described on Page XXXIVB-13-14.
NO
Structure is infested with termites?
-- → YES -- →
See IPM Information Package on STRUCTURAL PESTS: I for information.
NO
See applicable IPM information packages for information on other structural pests (e.g., bats, birds, mice, cockroaches).

II. STRUCTURAL PEST BIOLOGY AND ECOLOGY

1. Species Described:

A. Carpenter Ants - Members of the genus Camponotus; several species are known in the U.S. Workers may be up to 3/8 inch long, and queens may be up to 1/2 inch long. Within a species, there may be a large variation in the sizes of individual insects. See Smith (1965) for complete descriptions; also see key on page 119 of Anon., 1967.

B. Carpenter Bees - Species of the genus Xylocopa. These bees resemble bumblebees, but have hairless (thus shiny) black abdomens. Carpenter bees range in length from 1/2-1", and are usually metallic blue-black with green or purple reflections. Males bear a yellow spot on the face. Only females can sting, and are said to do so rarely. See Ebeling (1975) for complete descriptions; also see Page 116 of Anon. (1967) for key entry and figure of Xylocopa virginica.

C. Old House Borer - Hylotrupes bajulus, a cerambycid beetle. Adults are flattened, gray-black to dark brown-black, and have gray or yellowish hairs on their heads and wing covers. Females may reach 1 inch in length, while males are usually about 1/2 inch long. Larvae are gray-white and can reach 2 inches in length. The larva has a broad head and thorax, deep folds between abdominal segments, and one deep lengthwise groove in the center of the prothorax. Larvae have large, prominent jaws. See Ebeling (1975) for further details and photos.

D. Lyctid Powderpost Beetles - Members of the family Lyctidae. There are about 35 native species. Adults are small, elongate, redbrown to black, and may be 1/12-1/3 inch long. Their antennae are short, with two-segmented terminal clubs. Larvae are grublike in shape and appearance, with six legs, pigmented heads and mandibles, and enlarged spiracles on either side of the posterior end of the abdomen. Fully grown larvae may be up to 1/4 inch long. See Moore (1979) for additional information.

E. Anobiid Powderpost Beetles - Wood-inhabiting members of the family Anobiidae. There are more than 200 native species, but few are considered pests (Moore, 1979). Adults are 178-1/4 inch long, elongate and convex. The head is hidden from view by the hoodlike pronotum. Color ranges from black to red-brown. The wing coverings (elytra) usually bear characteristic grooves and pits.

Larvae are grublike, white with brownish head and mandible color. Two rows of brown spines run along the dorsal surface of the larva.

F. Flatheaded Borers - Members of the family Buprestidae. More than 150 native species are known. Adults are "boat-shaped" and flattened, with ridged wing covers. The beetles vary in length from 1/4" to 1 1/3", and may be dark in color with metallic highlights, or may be completely metallic colored. Larvae may reach 1-2 inches in length. They are white or yellow, legless, and have enlarged, wide flattened plates covering the prothorax. These plates give rise to the common name of these insects, although the larval head is actually small. Abdominal segments are narrow.

2. Geographic Distribution:

A. Carpenter Ants - Distributed throughout the United States.

B. Carpenter Bees - Distributed throughout the United States.

C. Old House Borer - A native of northern Africa, this species is now distributed over the Atlantic Coastal States as well as Mississippi, Louisiana and Texas.

D. Lyctid Powderpost Beetles- Found throughout the United States.

E. Anobiid Powderpost Beetles - Found in the contiguous 48 states, but not in Alaska or Hawaii.

F. Flatheaded Borers - Distributed throughout the United States.

3. Habitat:

A. Carpenter Ant - A wood nester with colonies occurring in logs, stumps, trees, posts and wood building components, including beams, doors, window sills and rafters. The nesting site in wood resembles an ornate carving due to the many smooth galleries produced. Most species prefer moist wood for nesting sites (Moore, 1979).

B. Carpenter Bees - Nest in the exposed dry wood of buildings, fence posts, telephone poles and other wooden structures. Prefers wood that is soft, seasoned and unpainted. Typical burrows have an entrance hole 1/2 inch in diameter and may extend 12 inches into the wood.

C. Old House Borer - Attacks structural timbers (especially roof timbers). Only the sapwood of softwood species is attacked. These insects were once thought not to nest in outdoor logs and stumps, but current research shows that they may.

D. Lyctid Powderpost Beetles - Lyctids attack the partially to fully seasoned sapwood of hardwood trees, with moisture content of 8-32% (Moore, 1979). The beetles may be found in dead branches of host species, stored lumber, finished wood, and furniture.

E. Anobiid Powderpost Beetles - Anobiids may attack both hard and soft woods. Sapwood and adjacent heartwood are invaded. Wood with a moisture content of 14-30% is preferred (Moore, 1979). Both host trees and structural wood (e.g., frame members) are attacked.

F. Flatheaded Borers - These insects attack living or dead trees, fences, structural wood, and furniture. Activity in dry or seasoned wood is not common (Moore, 1979). Infested wood which is used as lumber may support larval growth until it dries.

4. Hosts:

A. Carpenter Ants - Enter homes in search of food; they do not eat wood, but may eat sweets, and may cause damage to fabrics and paper products that are soiled with food. They are attracted to honeydew-secreting insects such as scales and aphids, and may prey upon other insects for their body fluids.

B. Carpenter Bees - Feed on pollen and nectar.

C. Old House Borer - Attacks softwoods, feeding on the sapwood.

D. Lyctid Powderpost Beetles - Favored hardwoods include oak, ash, hickory, maple, and walnut. Other species attacked include bamboo, magnolia, sweet gum, black gum, birch, persimmon, locust, elm, poplar, cherry, and sycamore (Mampe, 1982). Lyctids feed on the starch content of the wood.

E. Anobiid Powderpost Beetles - Attack many species of hard and soft woods. Some Anobiids may only attack one wood type, while others (e.g., Xyletinus peltatus) attack both (Moore, 1979). While starch and other cell contents are the major foods of these insects, they can also consume cellulose, which is digested with the aid of gut protozoa.

F. Flatheaded Borers - These insects attack the sapwood and heartwood of many tree species.

5. Life Cycles:

A. Carpenter Ants - The colony is usually initiated by a single queen who begins a nest in the soil, under a rock, or in a tunnel in a tree. The queen seals herself within a small chamber, and produces a small number of eggs. These hatch and develop into very small workers. When these workers mature (in 2-10 months) they care for the queen and the new eggs produced by the queen. Winged males and females are not produced until the colony's third year. Males live only long enough to mate. A mature colony may contain several active queens and up to 5000 workers.

B. Carpenter Bees - Carpenter bees are not social insects; many bees may inhabit a single piece of wood, but individual nests are built side by side. Carpenter bee adults overwinter in tunnels in trees, logs or structures. In the spring, they emerge and begin feeding and mating. After the nesting site is produced or selected, the female lays an egg in the end of the tunnel, produces a ball of pollen and nectar to provide food for the larva as it develops, and seals the end of the chamber. She then moves down the tunnel, producing new individual cells until she reaches the entrance hole. During this period the male guards the nest, flying at enemies that approach the entrance.

Adult males and females die in the early summer. At about the same time, the eggs hatch. Larvae pupate after about 40 days. Adults emerge from the pupal stage after about 15 days. They then leave the nest, feed for the rest of the summer and find a protected place to overwinter.

C. Old House Borer - Adults appear late in the summer and mate. The female lays her eggs in cracks or irregularities in wood. Larvae emerge within two weeks and bore into the wood. They feed on sapwood for periods ranging from 2-3 years (in moist wood) to 15 years (in dry wood, such as attic timbers)

(Moore, 1979). The interior of infested wood is often reduced to powdery frass, while the exterior may show no sign of damage. Larval tunnels may become completely filled with frass, in severe infestations. Pupation occurs in the spring, near the surface of the colonized wood. The pupal stage lasts about a week, but adults may remain in the wood for up to seven months before emerging to renew the cycle (Mampe, 1982). Emergence peaks in May, June, and July.

D. Lyctid Powderpost Beetles - Lyctids overwinter as larvae, which pupate in early spring. After a 2-3 week pupation, new adults emerge, fly about, and mate. Adults are strong fliers, but are only active at night. Eggs are laid 1-2 days after mating. Females taste wood to determine its suitability to support their offspring, then lay an average of 20-50 eggs in springwood vessels, pores, cracks, or crevices. After hatching, larvae tunnel along the wood's vessels, enlarging the tunnels as they develop. Young larvae produce straight tunnels, while older larvae tunnel in irregular fashion. Mature larvae bore pupal chambers just under the surface of infested wood. New adults cut circular holes to the wood surface, through which they exit. The entire life cycle may take from four to nine months.

E. Anobiid Powderpost Beetles - Anobiid females deposit up to 50 eggs on the surface of wood, under splinters, under debris, or in used exit holes. Eggs hatch in 6-10 days. Newly-hatched larvae crawl about on the surface before selecting an entry site. After tunneling straight into the wood, the larvae turn, tunneling with the grain and feeding on the sapwood. Larval development may take 2-3 years; growth rates are greatest in moist or decayed wood with high protein content. Dry wood may not support larval growth. Tunnels become packed with wood fragments and frass pellets. Mature larvae clear a section of their feeding galleries of frass, and pupate (generally in the spring) for 2-3 weeks. New adults bore tunnels straight to the surface and emerge. Adults mate soon after emerging and do not feed. Emergence peaks during the spring and summer. Adults may fly during the day or night. Outdoors, the life cycle may require only one year, while 2-3 years may be required indoors (Mampe, 1982).

F. Flatheaded Borers - Buprestids lay their eggs in crevices in bark, in wood, at the edges of wounds. Larvae tunnel under the bark and into the sapwood, producing flat galleries (oval in cross-section). After 1-4 years of development, larvae bore elongate pupal cells near the wood surface. Adults may emerge from these chambers at any time during warm weather. After emerging, they feed, mate, and lay eggs. (Individuals of the golden buprestid have emerged from wood up to 50 years after infestation occurred [Moore, 1979].)

6. Seasonal Abundance:

A. Carpenter Ants - Most colonies of outdoor ants experience a decline in the number of workers during the colder months. However, the carpenter ant is able to withstand cold because it generates glycerol in its body when the ambient temperature falls. Winged sexual forms are usually seen from May to July. Workers are seen foraging from April to June, and from September to October.

B. Carpenter Bees - Adults which have overwintered are seen in early spring. Newly emerged adults are seen in late summer and early fall.

C. Old House Borer - Adults may be observed from April to October in the South, and from June to September in the North. Activity peaks in June and July (Moore, 1979).

D. Lyctid Powderpost Beetles - Adult activity peaks in late winter and early spring.

E. Anobiid Powderpost Beetles - Adult activity occurs during the spring and summer, peaking during the first half of the warm season (Moore, 1979).

F. Flatheaded Borers - Adults may be seen any time during warm weather.

7. Response to Environmental Factors:

A. Carpenter Ants - Egg hatch may be delayed during cold weather. The larval stage may be prolonged during cold weather. In large colonies, winged forms may be produced during the winter.

B. Carpenter Bees - Activity of adults is triggered by rising spring temperatures. Suitable nesting sites may be used for several years.

C. Old House Borer - Larval development is most rapid in wood with 15-25% moisture. Development is difficult below 10%, or in wood with less than 0.2% protein.

E. Lyctid Powderpost Beetles - Eggs are not laid in wood with less than 3% starch. Larval activity is greatest in wood with 10-20% moisture, although wood containing 8-32% moisture is attacked.

F. Flatheaded Borers - Certain buprestids are attracted by the smells of numerous burning materials, and are stimulated by heat. These species normally oviposit in scorched coniferous wood, and are attracted to forest fires in nature.

8. Impact of Structural Pests:

8.1 Direct Impact:

A. Carpenter Ants - Any wood in a building may be damaged by these pests if it is infected by wood rot fungi. Damage may occur when wooden structural members are hollowed out for nesting. Workers may bite if irritated.

B. Carpenter Bees - Wood structural members (especially facia boards) colonized by large numbers of bees can be extensively damaged. Wooden barrels or tanks can develop leaks due to bee tunneling.

C. Old House Borer - Serious damage to roof timbers can result from borer tunneling. Attic and floor timbers may also be damaged. Furniture may also be damaged. Widespread infestations cause structural damage and require expensive control measures.

D. Lyctid Powderpost Beetles - Any hardwood with sufficient moisture may be seriously damaged by these pests. These beetles attack hardwood flooring, timbers, plywood, wood crates, tool handles, gunstocks, furniture, and other wood articles.

E. Anobiid Powderpost Beetles - Wooden girders, beams, foundation timbers, furniture, and wood fiber wallboard may be attacked and severely damaged by these pests. Damage may reduce the value of antique furniture and other wood. The presence of these pests may reflect a moisture or wood decay problem.

F. Flatheaded Borers - Very little direct damage to structural wood is caused by these insects; they have usually completed their development by the time infested wood is cut. Adults emerging from infested wood may produce holes in framing or floor boards.

8.2 Indirect Impact:

A. Carpenter Ants - These pests may damage sized paper or fabric goods by feeding. Food-soiled items may also be fed on (Pfadt, 1978). Large numbers of ants may cause aesthetic problems.

B. Carpenter Bees - People may be annoyed or frightened in the vicinity of active infestations by the noisy, threatening behavior of (stingless, but large) males protecting their nests. If sufficiently irritated, females will sting. Avoidance of infested structures by people may result. The activity of carpenter bees may attract woodpeckers, which may enlarge the bee cavities to obtain larvae. Woodpecker damage may be more severe than that done by the bees.

C. Old House Borer - Visitors to heavily infested buildings may be alarmed by the "chewing" or clicking sounds made by larvae feeding on timbers.

D. Lyctid Powderpost Beetles - Adults may cause aesthetic problems by their nocturnal flight, especially if they emerge indoors. They are attracted to lights, and may crawl about on floors, windows, and other surfaces. Powdery frass may accumulate beneath emergence holes.

E. Anobiid Powderpost Beetles - The adults of some species could create nuisance problems by their flight activity and attraction to lights.

F. Flatheaded Borers - Emergence holes in roofing, siding, or trim may accumulate water and begin to decay or leak. Indoor emergence may cause minor nuisance problems.

9. Natural Enemies:

A. Carpenter Ants - Ebeling (1975) states that these ants are parasitized by two species of phorid flies; especially by Apocephalus pergaudei. In addition, the fungi Cordyceps unilateralis, Desmidiospora myrmecophila, and Beauveria globuifera parasitize carpenter ants. None of these agents is known to provide useful levels of control. The pileated woodpecker is known to feed on carpenter ants.

B. Carpenter Bees - The best known predators of these insects are woodpeckers, which will enlarge bee nest tunnels to feed on larvae. Woodpeckers do not exert useful levels of control of carpenter bees. Woodpeckers may cause more damage excavating bee larvae than do the bees themselves.

C. Old House Borer - Woodpeckers are believed to feed on larvae in treestumps.

D. Lyctid Powderpost Beetles - Numerous insects are predators or parasites of Lyctids, including checkered beetles (Cleridae), and several genera of wasps (Ebeling, 1975). The level of control exerted by natural enemies is usually not sufficient.

E. Anobiid Powderpost Beetles - Information not available.

F. Flatheaded Borers - Information not available.

III. STRUCTURAL PEST MANAGEMENT

1. Population Monitoring Techniques:

A. Carpenter Ants - Annual inspection of structures and surrounding areas should be made for evidence of infestation, including wandering ants, partial bodies of ants, potential food sources, and nesting sites. Nests are often revealed by piles of sawdust-like bits of wood under small openings in wood. The openings enter into large galleries within the wood. Outdoor nests are usually found in tree parts which are rotting or retaining excess moisture, under boards, in piles of leaves or debris, or under rocks. Carpenter ants may forage up to 300 feet from their nests, so inspection zones should extend at least this distance from each structure monitored. Look for ant trails in grass in areas of heavy infestation.

B. Carpenter Bees - Structures should be inspected regularly during the nesting season for the presence of nest entrance holes (circular cavities, about 1/2 inch in diameter) leading into the infested wood. They are usually oriented across the grain of the wood and usually turn at a right angle within one inch of the entrance, after which they follow the grain. Piles of sawdust may be visible below entrance holes. Nest holes may be found in wooden siding, window sills, eaves, railings, fences, and outdoor furniture. Nests may also be revealed by insect excretions and pollen which may be smeared on boards, windows, or siding below the entrance holes.

C. Old House Borer - Structures should be inspected annually for evidence of borer infestation. Evidence includes the rasping or clicking sounds made by larvae while boring; the presence of powdery wood residue in tunnels, visible when the wood is probed with a sharp instrument; the presence of 1/4-inch diameter, oval emergence holes of adult beetles; and larvae or adults themselves. Inspection of areas outside structures is probably not necessary, since the evidence suggesting that H. bajulus nests out of doors is very limited (Mampe, 1982).

D. Lyctid Powderpost Beetles - Annual inspection of structures and their contents should be made for evidence of lyctid infestation. Such evidence includes the presence of circular emergence holes (1/32-1/16 inch in diameter) in wood surfaces, piles of floury frass (not pellets) on or under wood, and (rarely) dead adults. Night inspections during peak emergence may show flying adults.

Slight jarring of infested wood will cause lyctid frass to fall freely from entrance holes.

E. Anobiid Powderpost Beetles - Structures and wood articles should be inspected annually for evidence of infestation, including small (1/16-1/8 inch) exit holes in wood, piles of frass pellets which accumulate under the holes or on wood surfaces, and occasional adults. Anobiid frass is light colored when fresh, and is tightly packed in larval tunnels. The pellets may be football or bun-shaped.

F. Flatheaded Borers - Annual inspections should be made for flattened ovoid exit holes up to 3/8" in diameter in moist wood. Adults may occasionally be seen. In wood with bark edges left on, larvae may be heard chewing under the bark until the wood dries.

2. Threshold/ Action Population Levels:

A. Carpenter Ants - Since these insects may cause severe structural damage if unmanaged, the presence of any carpenter ants within a structure is cause for further attention. The detection of any evidence of active nesting within a structure should trigger management procedures.

B. Carpenter Bees - While small numbers of carpenter bees may not cause significant levels of damage to wood, the activity of predators (e.g., woodpeckers) may cause severe damage. Therefore, any nest holes observed should be treated (see Section III 3 B). Bees will repeatedly infest the same galleries; treatment of old entrance holes will prevent such reuse.

C. Old House Borer - Any evidence of active borer infestation should trigger managment procedures, since these insects can severely weaken an infested structure.

D. Lyctid Powderpost Beetles - Any evidence of active infestation should trigger management activities.

E. Anobiid Powderpost Beetles - Since damage by these insects can become severe in moist wood, any evidence of active infestation should trigger management activities, especially where moisture problems may occur.

F. Flatheaded Borers - The danger of severe damage to structural wood by buprestids is slight, since infestation occurs before the wood is cut. Exit

holes which could collect water should be noted and repaired during monitoring for other boring insects, but damaging numbers of these species are unlikely to occur in structural wood or wood articles.

A sample inspection report form is shown on Pages XXXIVB- 20,21. Such a form should be used to record and maintain inspection records for each building.

3. Management Alternatives-Nonchemical:

A. Carpenter Ants -

1. Trim all plants adjacent to each structure so that no branches touch the structure.

2. Correct moisture problems, such as leaking roofs, plumbing, downspouts, etc.

3. Increase ventilation in attics and basements to reduce moisture accumulation.

4. Eliminate soil-wood contact points (see IPM Information Package on Termites for details), and replace rotted or water-damaged wood with pressure-treated wood when appropriate.

5. Remove dead tree stumps within 50 feet of each structure, and repair trees with damaged limbs, damaged crotches, or holes.

6. Store firewood off the ground and away from structures (not inside buildings). Discard infested logs.

7. Good sanitation procedures will reduce the presence of foraging ants.

B. Carpenter Bees -

1. Seal entrance holes in wood with wood putty or caulk and seal small holes (e.g. nail holes) which could be enlarged by carpenter bees.

2. Painted or varnished wood surfaces are less likely to be attacked than unpainted wood. If possible, treat exposed wood surfaces after entrance holes are filled. Consult with your Regional Historic Architect before treating historic structures.

C. Old House Borer -

1. Removal of infested wood can reduce the likelihood of future infestations.

D. Lyctid Powderpost Beetles -

1. Wood to be used in construction should be kiln-dried and inspected for beetle damage.

2. Replace infested wood, where possible. Use pressure-treated wood where moisture is likely.

3. Correct moisture problems such as leaking roofs, plumbing, downspouts, etc.

4. Provide adequate ventilation of attic and basement areas, to prevent moisture accumulation. Use vapor barriers where possible.

5. If possible, construct structures to allow the use of central heating, which aids in keeping wood dry.

6. Eliminate bark edges from structural wood, to reduce the chance of attack by species that feed under bark.

E. Anobiid Powderpost Beetles - See Section III 3 D.

F. Flatheaded Borers - See Section III 3 D. Those procedures that prevent or reduce attack by other wood-boring beetles will also aid in reducing damage by these insects.

4. Management Alternatives-Chemical:

A. Carpenter Ants - A mixture of pyrethrins and silica aerogel (TriDie® or Drione®) can be used to treat nests by injection into holes drilled in infested wood.

B. Carpenter Bees - Entrance holes should be injected thoroughly with silica aerogel and pyrethrins, or 5% carbaryl. If entrance holes are treated after adult activity has ceased for the year (around mid-spring or early fall), the holes should be sealed with caulk after treatment. If adults are active at the time of treatment, sealing should be delayed, so the insects may pass through the exit hole and contact the dust. Any new adults will emerge through the hole and contact the dust as well. In the fall, treated holes can be filled and the surface painted or varnished.

C. Old House Borer - Localized infestations can be spot-treated with chlorpyrifos (Dursban TC®). Heavily infested structures or furniture may be fumigated with methyl bromide or sulfuryl floride to eliminate borers. Fumigants must be applied only by certified applicators using the correct equipment. Contact your regional IPM Coordinator to determine which treatment will be most effective in your situation.

D. Lyctid Powderpost Beetles - See Section III 4 C.

E. Anobiid Powderpost Beetles - See Section III 4 C.

F. Flatheaded Borers - See Section III 4 C.

5. Summary of Management Recommendations:

A. Carpenter Ant -

1. Conduct annual inspections of all structures and surrounding areas for signs or other evidence of infestations.

2. Remove infested or water-damaged wood where possible, control water leakage, and improve ventilation of attic and basement areas.

3. Remove outdoor nesting sites near buildings. Remove potential food sources, and store firewood away from structures.

4. Prune plantings to prevent contact between buildings and branches.

5. If necessary, treat with silica aerogel/ pyrethrin mixture (Tri-die, Drione).

B. Carpenter Bee -

1. Conduct regular inspections for nesting holes during spring and summer.

2. Seal holes in wood that bees could enlarge.

3. Paint and varnish exposed wood surfaces.

4. Treat nest holes with silica aerogel/pyrethrin mixture, or carbaryl and seal (when appropriate) with caulk. Paint or varnish surfaces.

C. Old House Borers -

1. Conduct annual inspections of structures for evidence of infestation.

2. Remove infested wood where possible.

3. Provide dry conditions by maintaining adequate ventilation and heating, and by repair of moisture problems.

4. Spot treat infestations with chlorpyrifos (Dursban TC) when necessary.

5. Fumigate structures as needed.

D. Lyctid Powderpost Beetles - See Section III 5 C.

E. Anobiid Powderpost Beetles - See Section III 5 C.

F. Flatheaded Borers - See Section III 5 C.

IV. BIBLIOGRAPHY

Copies of the following articles can be obtained by contacting the IPM Coordinator, WASO.

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DiSalvo, C. 1984. Carpenter bee management. National Park Service, Washington, D.C. np.

Ebeling, W. 1975. Urban Entomology. Univ. of California Press, Los Angeles. 695 pp.

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Smith, M.R. 1965. House-infesting ants of the eastern United States. Agricultural Research Service, U.S.D.A., Washington, D.C. 105 pp.

V. SAMPLE STRUCTURAL PEST MONITORING REPORT FORM (SIDE 1.)

Structure Name or Number _____
Structure Address or Location _____
Person to Contact _____ Phone _____
Survey Date _____ Inspector _____

Structure Data (Check One):

1. TYPE OF STRUCTURE
   basement___ slab___
   crawl___ combination___

2. FOUNDATION
   concrete___ hollow block or tile___
   stone___ multiple brick___
   brick veneer___ single brick___
   piers only___ combination___

3. EXTERIOR
   wood___ hollow block___
   stone___ stucco on frame___
   brick___ stucco on masonry___
   surfaces painted____ varnished_____

4. PORCHES
   wood___ dirt filled___
   masonry___ hollow___
   _____ over masonry___

5. BASEMENT
   ceiling finished___with_____
   walls finished___with_____
   floor finished___with_____
   venting sufficient?___
   vents screened?___

6. SLAB
   supported___ floating___
   monolithic___ wood over slab___
   floor covered___with_____
   plumbing accessible?___
   heating accessible?___
   type of heat_____
   blue prints available?___

7. GENERAL INFORMATION
   paving against foundation___feet
   planters___ shrubs, plants___
   plants touching building?____
   soil type_____
   crawl space clearance___inches
   are all areas accessible?_____
   must openings be made?___
   are wood supports in contact with ground or embedded in slab?___
   are form boards present?___
   buried wood waste present?___
   accumulations of water present?___
   plumbing leaks present?___
   is grade correct?___
   wells or other special precautions?___
   nearby sources of infestation (trees, posts, woodpiles, etc.)_____
   are holes visible in surface wood?_____

Inspection Data:

1. INFESTATION FOUND
   major insect species found _____ is infestation active?____
   other insects?___ species_____
   wood decay fungi?___

2. LOCATION, INTENSITY OF INFESTATION
   Describe fully, showing locations on structure diagram on reverse side of this sheet.

3. TREATMENT/REPAIR RECOMMENDATIONS

4. DATE OF TREATMENT_____ PERSON/FIRM PERFORMING REPAIR:
DATE OF REPAIR_____ _____

5. REMARKS:

6. STRUCTURE DIAGRAM: show infestations, needed repairs, and nearby sources of insects.

NATIONAL PARK SERVICE
IPM Information Package

TENT CATERPILLARS

Final Report

February 1984

Submitted To:

Dr. Michael Ruggiero
Biological Resosources Division
National Park Service
Washington, D.C.

Submitted By:

John Muir Institute
743 Wilson Street
Napa, California 20852

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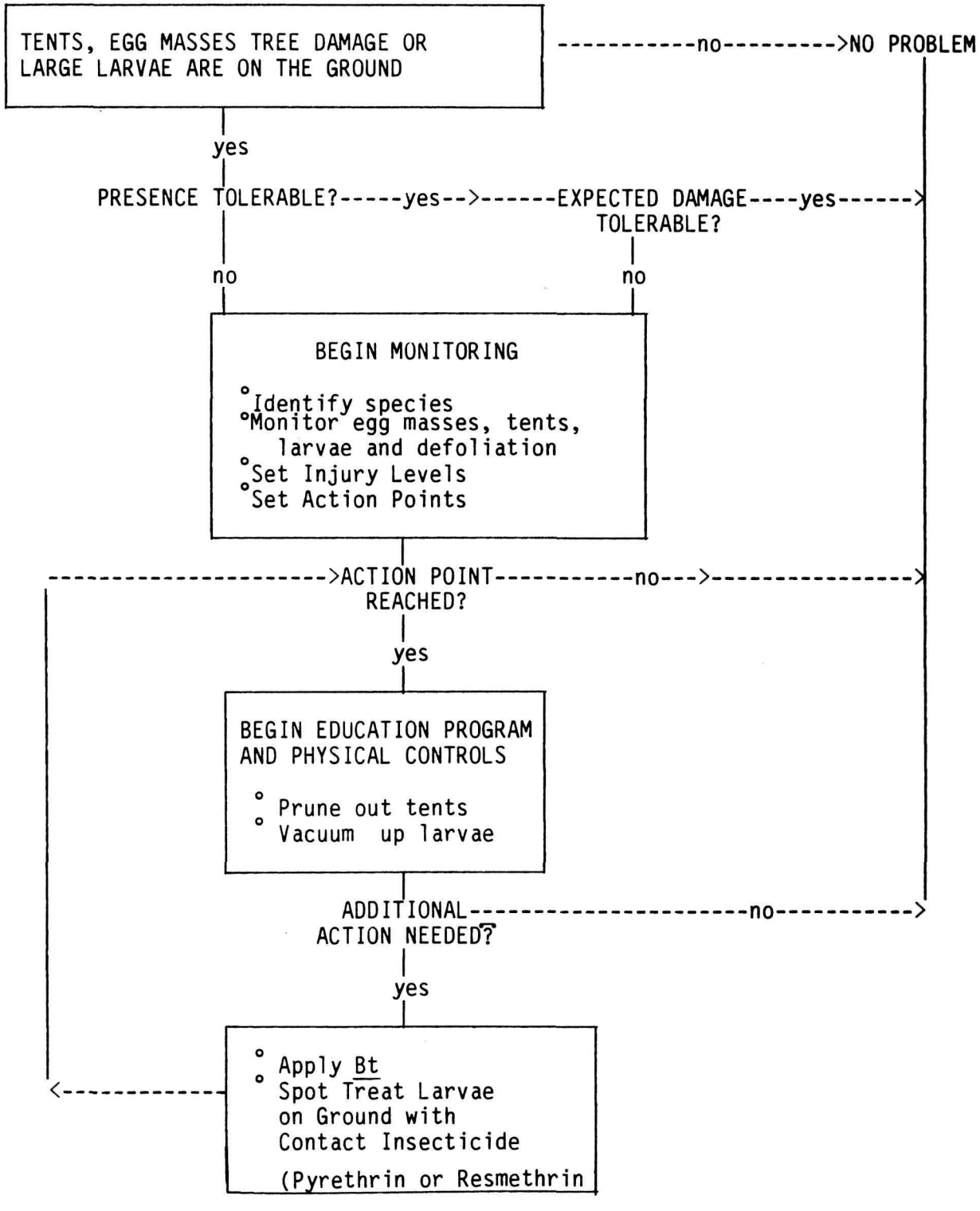
I TENT CATERPILLAR IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are needed consult with NPS management staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



II BIOLOGY AND ECOLOGY OF TENT CATERPILLARS

1. Species Described:

In North America, six recognized species in the genus Malacosoma (Lepidoptera: Lasiocampidae) feed on more than 25 plant genera in the Rosiaceae, Fagaceae, and Salixaceae. The six North American species, their common names, distributions, tent-making characteristics and major food plants are listed in Table 1. Periodic massive outbreaks resulting in defoliation of large areas mark the group as economically important.

The adult moths are relatively unfamiliar because of their drab coloring and short life, but the larvae are well known because of their conspicuous tents although the most damaging species, the forest tent caterpillar, M. disstria, does not make a tent, and two other species, the Sonoran tent caterpillar, M. tigris, and the Pacific tent caterpillar, M. constrictum only make small tents. Excellent color photographs of the eastern tent caterpillar, M. americanum, were published by Fitzgerald (1983). Johnson and Lyon (1976) also picture the life stages of the eastern tent caterpillar and that of the fall webworm, Hyphantria cunea with which it may be confused. Fall webworm tents occur on the tips of branches while tent caterpillar tents occur within the canopy.

The more important distinguishing characteristics useful for separating the tent caterpillar species are summarized in Table 2. Additional details and microscopic characteristics can be found in Stehr and Cook (1968). The same authors also provide methods for distinguishing the two subspecies of M. constrictum, the six subspecies of M. californicum, and the three subspecies of M. incurvum. Keys to the egg masses, mature larvae and adult males and females of the North American species are provided by Stehr and Cook (1968). Palearctic species include: M. neustria, M. castrensis, M. franconicum, M. alpicola, M. luteus, and M. laurae (Lonjonquiere 1978). M. indica is known from India.

2. Life Cycle:

The life cycle of all the Malacosoma species is similar. Only one generation occurs per year. 150-300 eggs are laid in masses encircling, or partially encircling small twigs of the host plant. Some species may deposit their eggs as a flat mass on larger branches or trunks near the ground. As the eggs are being deposited they are covered by a frothy substance called spumaline produced from the

Table 1.

NORTH AMERICAN TENT CATERPILLARS IN THE GENUS *MALACOSOMA**

SPECIES	COMMON NAME (Tent Caterpillar)	DISTRIBUTION	PREFERRED FOOD PLANTS
M. disstria	Forest	US & Canada	many deciduous spp.
M. tigris	Sonoran	SW US	various oaks
M. constrictum	Pacific	CA coast to WA	western oaks
M. americanum	Eastern	E US	Prunus, Malus, Crataegus
M. californicum	Western	W US & other US	many species
M. incurvum	Southwestern	SW US & Mexico	southwestern cottonwood, etc.

* Adapted from Stehr and Cook (1968).

Table 2.

IMPORTANT FIELD DIAGNOSTIC CHARACTERISTICS OF
NORTH AMERICAN TENT CATERPILLARS IN THE GENUS *MALACOSOMA**

SPECIES	EGG MASS	MATURE LARVAE	TENT	COCOON
M. disstria	helical ring, brown spumaline	yellow-buff spots on each segment	none	leaves webbed together with outer silk envelope
M. tigris	helical ring no spumaline	eighth abdominal segment almost completely black	small silken mat	no silk envelope: white powder visible
M. constrictum	helical ring yellow spumaline & large bubbles	hourglass shaped dorsal blotch bordered by black spots	small silken mat	no silk envelope: white powder visible
M. americanum	clasping mass with seam on small twigs or trunk, dark brown spumaline	continuous even yellow-white mid-dorsal stripe	large	no silk envelope: bright yellow powder visible
M. californicum	similar to *M. americanum*	broken mid-dorsal stripe formed by bluish dash on each segment	large	often with outer envelope
M. incurvum	similar to *M. americanum*	difficult to separate from *M. californicum*	large	no outer envelope: whitish or pinkish powder

* Adapted from Stehr and Cook (1968). The adults can be distinguished definitively by microscopic examination of the epiphysis, a structure on the tibia of the foreleg, pictured by Stehr and Cook.

accessory glands of the female. There is evidence to indicate this material helps protect eggs from parasitoids (Witter and Kulman 1979). Eggs are laid in midsummer, and the embryos mature into fully-formed larvae within 2-3 weeks. They remain in the eggs, passing the late summer, fall and winter in an arrested state (diapause and hibernation) until the time when new leaves start to appear in the spring (Blais et al. 1955). This may occur during late January in Florida and as late as June at high elevations in the western mountains.

The larvae chew their way out of the eggs and through the spumaline, then begin eating buds or leaves and constructing "tents". The larvae remain gregarious throughout their larval development until the prepupal stage when they individually seek pupation sites. Tent building species crawl out of their tents to feed, laying down a strand of silk with which to find their way back to the tent. Tents function to exclude natural enemies, provide shelter from extreme temperatures and humidities, facilitate molting and aid in colony communication (Fitzgerald and Willer 1983). Usually one tent per egg mass is produced. Multiple colony aggregates derived from more than one egg mass may occur on single trees. The forest tent caterpillar, M. disstria, which does not construct a tent, aggregates in masses on a branch or the crotch of a tree.

The larvae pass through five or six instars in four to eight weeks and molt in or on their tents. During their last instar, when about two inches long, they lose their gregarious habit and wander extensively, searching for food. At this stage they also become rather indiscriminate feeders and attack many species of plants. Eventually they select a site within the old tent, inside a log, beneath loose bark, or between folded leaves and spin their cocoons. The prepupal stage lasts about two days and the pupal stage up to two weeks. Adult moths emerge in late afternoon or early evening, mate the first day, begin laying eggs immediately and die in a few days. Male and female moths do not have functional mouthparts and take no food.

All six species are probably native to North America and are capable of occurring in outbreak numbers. An outbreak refers to a large population of caterpillars which causes complete defoliation over many acres. The eastern tent caterpiller was recorded as exceedingly abundant in and before 1646 (Britton 1935). Epidemic populations of the forest tent caterpiller were recorded in eastern North America as early as 1791 (Baird 1918).

Although many authors refer to the cyclic nature of these outbreaks, Stehr and Cook (1968) who produced the definitive work on this genus in North America, gather evidence from other workers indicating that the timing of outbreaks can vary considerably from one location to another. In some areas outbreaks can reoccur in as short a period as three years. In other regions outbreaks have occurred only once in a 35 year period. Outbreaks in a specific locality usually persist for 1 to 4 years before being brought under control by various factors such as disease, parasites, starvation, weather and combinations of these factors.

3. Natural Enemies:

In summarizing over 500 papers mentioning natural enemies of Malacosoma species in North America Witter and Kulman (1972) indicate that there is documentation for 14 species of egg parasitoids, 113 larval and pupal parasitoids, and a similarly large number of insect, bird, amphibian and mammalian predators of tent caterpillars. In addition tent caterpillars are subject to attack by nematodes, viruses, protozoa, fungi and bacteria.

The importance of natural enemies is repeatedly indicated by many workers but Witter et al. (1972) prepared the first known life tables for the forest tent caterpillar which presents calculated values for various causes of mortality during 1968 and 1969 in northern Minnesota. Eight percent of the eggs, about 25% of the larvae, and about 60% of the pupal stage were killed by various natural enemies during both years. Differences in generation survivorship between the years (0.7% in 1968 and 2.2% in 1969) was accounted for by 1) changes in pharate (the larval stage which overwinters within the egg) larval mortality caused by severe weather conditions during the winter, 2) death of first instar larvae from spring frosts, and 3) variations in pupal mortality, principally from attack by the pupal dipteran parasitoid, Sarcophaga aldricki.

Witter and Kulman (1979) continued the above work over a six year period (1967-1973), documenting changes in pest and natural enemy populations during a complete "epidemic" cycle. They indicate egg parasitism rates fluctuated from ca. 4-10% during this period. This is similar to most other studies of egg parasitism with Malacosoma spp. The braconid, Rogas sp., was the only early larval parasite, but hyperparasites reduced its effectiveness during latter years of the outbreak.

Late stage larvae attacked primarily by three tachinid flies had parasitism rates which varied from ca. 3-23% of 5th stage larvae. S. aldrichi became the dominant pupal parasite after the first year with parasitism rates rising to about 60% in the 3rd or 4th year. A combination of heavy pupal mortality and prior reduction from severe weather or starvation is considered as predisposing conditions for collapse of epidemic caterpillar populations.

III TENT CATERPILLAR MANAGEMENT

1. Population Monitoring Techniques:

Hodson (1941) working in Minnesota with the forest tent caterpillar evaluated methods for estimating population sizes and defoliation levels. The principle host tree was the aspen, Populus tremuloides. He evaluated egg, larval and coccoon sampling methods. The most valuable data were from egg "bands" or masses. These were obtained by felling trees after the leaves had fallen and by bending smaller (<2 inch D.B.H., = Diameter at Breast Height) trees down so egg masses could be counted. The counts made from these felled trees were compared to those made previously with binoculars.

Although the binocular method mostly underreported the number of masses, Hodson considered it useful as a relative measure for deciding whether treatments may be necessary. The actual counts of egg masses on 10 trees was 212 ($\bar{x}$ = 21.2). Two observers using binoculars each underestimated the number of egg masses by 145 and 131 (about 65%). The masses are about the color of twigs and are easily confused with bud scars. Egg mass counts could be useful with other Malacosoma species, especially where trees are small.

Connola et al. (1957) also tested the binocular method and obtained approxi-mately the same results. However, they compared egg mass counts by sampling 10 twigs and by counting egg masses from cut trees. They found that twig samples cut with pole pruners detected about ¼ of the total egg mass count. These workers elaborated the use of egg mass collection data further showing how the number of egg masses could be used to estimate defoliation. They also indicate that cut-twig samples is a highly efficient sampling system.

Frass collections made by placing funnels, cloth traps, or sticky paper beneath the crown of infested trees has been used to determine the species, stage of development and relative density of larval populations. Hodson (1941) cites earlier workers who used this technique in field applications, but his own work was conducted with laboratory colonies. He indicated the weight, length and width of frass samples which correspond to the different instars. This technique can be used in field sites to show when the early instars begin feeding as they are particularly difficult to detect. The frass technique is subject to error when other frass-producing species are present and can be confused with the primary insect.

With tent making Malacosoma species the tents appear with the onset of larval feeding and thus provide a visual method for estimating potential damage. With such species frass collections would be useful only for the short period between larval hatch and the point when the tent can be detected visually. However, frass collections will be subject to some degree of error as some frass accumulates in the tent and is difficult to measure or estimate.

The cocoon sampling methods Hodson evaluated were: timed collections, temporary sample quadrats, permanent sample quadrats, general collecting and tree collections. Timed collections, where cocoons were hand picked for a definite length of time (usually three minutes), compared favorably with square meter quadrant counts, although they were recognized as not representative for very low and very high populations.

By calculating the number of larvae (from the number of masses per tree, the number of eggs per mass, and the percentage survival), the number of leaves they are known to eat per tree, and the estimated total foliage on the tree, a "defoliation ratio" can be obtained. This ratio (the number of leaves to be eaten divided by the estimated number of leaves on a tree) gives a measure for predicting the extent of defoliation. Ratios greater than 1:1 predict complete defoliation. This information has been simplified to a table (see Table 3) where D.B.H. (diameter at breast height) of the target tree and number of egg masses would be indicative of complete defoliation. However, Hodson indicates that in certain situations this method did not function to predict expected catastrophic population numbers.

The best means of determining injury levels and action points is to monitor egg masses in the fall to gain an estimate of how large the early larvae populations will be in the spring. Sampling again in the spring is needed to correlate fall egg mass levels with spring larvae populations (e.g. how many larvae actually hatch out of the eggs). If populations are high, frequency of monitoring should be adjusted to insure that decisions regarding treatments can be made before unacceptable damage ocurs. Weekly monitoring may be warranted during spring hatch if populations appear high. Less frequent monitoring (e.g. bi-weekly or monthly), may be sufficient with lower populations.

Table 3.

THE NUMBER OF EGG MASSES CAUSING COMPLETE DEFOLIATION IN RELATION TO TREE DIAMETER IN NORTHERN MINNESOTA ON ASPEN, *POPULUS TREMULOIDES*, BY THE FOREST TENT CATERPILLAR, *MALACOSOMA DISSTRIA**

DIAMETER AT BREAST HEIGHT (inches)	(centimeters)	NUMBER OF EGG MASSES DETECTED **
1	2.5	2
2	5.0	5
3	7.5	9
4	10.0	11
5	12.5	14
6	15.0	19

* From Hodson 1941.

** The number of trees felled to collect these masses was not indicated.

As tents or aggregates form staff should be able to determine how many "tents" per tree can be tolerated without exceeding the aesthetic injury level. When the fall and spring monitoring program indicates that the number of tolerable tents will be exceeded, treatments can be implemented. If the pest species is the forest tent caterpillar which does not form tents, the number of spring larval aggregates rather than the number of tents will have to be counted.

In northern Minnesota during the early years of a large forest tent caterpillar outbreak lasting five years Hodson (1941) indicates hatching occurred on May 12, 1936 and May 10, 1937. The first overwintering egg masses were discovered on July 29, in 1937. In other areas and with other species the spring hatch will occur about the time of bud break and leafing out.

In conjunction with the egg mass numbers, the number of tents per tree, cocoon numbers, frass collections, or defoliation ratios, etc., natural enemy populations also need to be measured in order to be able to predict outbreaks. The most important measurements of natural enemy populations are of the larval and pupal parasites, Rogas sp. and S. aldricki. Rogas can be sampled by collecting larval specimens and rearing them temporarily until pupation or until a "mummy" (or parasitized specimen) is formed. Larval dissections also can be performed but considerable skill is required in order to distinguish the local parasite and hyperparasite larval forms with precision.

Larvae reared to the pupal stage and collected pupae can be held in small vials with cotton stoppers until parasites emerge. Percentages of the different representative larval or pupal collections can be calculated from dissections and/or emergence data. Total percentages of all primary parasites and hyperparasites should be added since hyperparasites emerge from primary parasites. The impact of parasites on the pestiferous larval herbivore population is assessed by summing all percentages for particular larval collections and plotting trends in comparison with similar trends of larval tent caterpillar densities. More elaborate statistical procedures for assessing natural enemy impacts are discussed in van den Bosch et al. (1982).

2. Threshold/ Action Population Level:

Injury level refers to the point in the growth of the pest population when the numbers of pest organisms are sufficient to cause some unacceptable kind or degree of structural, economic, aesthetic or medical damage (injury). Where the damage is primarily an aesthetic one it may be useful to substitute the phrase "tolerance" levels as a synonym for "injury" levels. In other words, one needs to determine how much change from the "ideal" appearance can be tolerated before treatment actions against the target pest are required.

Several questions should be considered in establishing an injury/tolerance level. These include:

a. will defoliated trees die?
b. will defoliated trees cause unacceptable aesthetic injury?
c. what number of tents or larval aggregates per tree will cause unacceptable aesthetic injury?

In natural areas tent caterpillar outbreaks should be regarded as part of the natural ecosystem. Defoliated trees are seldom killed. However, if trees are under other stresses (e.g. drought, disease) repeated defoliations may result in death of some trees. However, it may be appropriate to tolerate even relatively large scale tree mortality in a natural area since such an occurrence is part of the natural dynamics of the forest.

In developed areas where visitor use is high, large numbers of tents, larvae or egg masses may warrant treatment even though no permanent damage to the vegetation is likely to occur. This is due to the short-term "aesthetic" damage to ornamental plants which may result from high populations of caterpillars, or the obvious presence of large numbers of larvae seeking pupation sites after finishing their feeding period.

Visitors will require interpretive services during tent caterpillar outbreaks either to reduce their fears or to satisfy their curiosity. These educational services can impact attitudes and consequently the tolerance for various populations of the pest.

In the short term, one way to determine injury level guidelines particularly for "aesthetic injury" during tent caterpillar outbreaks might be to determine the costs in staff time to educate the public on the reasons no treatment is occuring compared to the costs (labor, materials, potential political and financial liability) of applying treatments.

The action point is that point in time when pest suppression must take place to prevent the injury level from being reached (or the tolerance level from being exceeded).

There are three periods when actions should be taken:

a. in the fall or winter against the egg masses
b. in the spring after all eggs have emerged
c. during large outbreaks when large larvae move from defoliated trees and wander in search of pupation sites

During the fall and winter, treatments can occur anytime after all the eggs have been laid and leaves have fallen so that masses are visible. Timing is critical for early spring treatment of the larvae as the insecticide of choice is Bacillus thuringiensis (Bt), a stomach poison, and the larvae have to actively ingest a lethal dose. The spring action point will occur after all masses have hatched but before larvae have ceased feeding prior to pupation. Projected impact of natural enemies based on information obtained from monitoring should be factored into decisions to treat.

3. Management Alternatives-Nonchemical:

Indirect suppression strategies and tactics are those that change the conditions that create or define the pest problem. Examples are:

a. design or redesign of the landscape, structure or maintenance for the purpose of reducing or eliminating the pest problem;

b. modifying the habitat in some major way to discourage the pest species;

c. human behavior changes including the alteration of use patterns or maintenance practices contributing to the pest problem, or education to increase tolerance levels for the "pest" species or the aesthetic damage it causes.

In developed areas where tent caterpillars are a chronic pest problem the landscape design process should specify plant species which are not susceptable to this pest group. Similarly, existing landscapes which are not historically important nor part of the natural setting also can be redesigned to minimize available habitat for tent caterpillars.

For example plant species with extrafloral nectaries that attract ants such as Formica obscuripes which prey on tent caterpillars (Tilman, 1978) could be added to the landscape Where unacceptable pest numbers repeatedly occur, the habitat surrounding the seasonally-infested plants could be screened from view by additional plantings.

There are a number of case histories where habitat alterations improved survival or increased the reproductive potential of natural enemy populations and reduced pest populations. A short review of this subject is provided by Rabb et al. (1976). Installing nest boxes to increase insectivorous bird populations and predacious wasps (i.e. Polistes spp.) have been used in some settings to increase predation rates against other caterpillar species. Beyer and Moore (1980) remark on the predatory effects of various cuckoos on tent caterpillars and Jackson (1979) points out that in order to allow a build-up of these voracious caterpillar predators there must be at least patches of thicket in the understory as this habitat is where they select nest sites. Leius (1967) shows that orchards rich in wild flowers had 18 times as many parasitized eastern tent caterpillar pupae as those orchards with poor wildflower undergrowth.

During normal pruning activities efforts should be made to remove egg masses if a pest problem is anticipated.

In periods when large outbreaks are occurring efforts to educate visitors and staff about the biology and ecology of the tent caterpillar species in question can increase tolerance levels and reduce public pressure for treatments. Similarly, if treatments take place, educational efforts should be directed to describing why the decision to treat was made and the nature of the treatments selected.

In small areas where an aesthetic problem occurs pruning out tents or scraping egg masses may provide temporary local suppression. On highly prized ornamentals (e.g. Japanese cherry trees at Hains Point in the National Capital Region of the NPS) spot pruning with a pole pruner was sufficient as a management technique when a small number of tents were present. The use of a portable vacuum for removing large larvae which have finished feeding and have begun wandering can be useful where they are causing intolerable aesthetic damage.

Two deliberate biological control approaches are useful in managing tent caterpillar problems: conservation and augmentation of natural enemy populations. The conservation of existing natural enemy populations by minimizing

damage from human activities, e.g. treatments with non-selective agents, habitat destruction, etc. is an essential part of maintaining existing natural enemy complexes. Some methods for augmenting natural enemy populations have been discussed under the Design or Redesign section. The use of the microbial control agent, Bacillus thuringiensis (Bt) is considered an aumentative biological control tactic because the microbe occurs naturally and universally as an insect pathogen but is augmented by periodic releases when increased populations will reduce an insect pest population.

In large population outbreaks applications of the selective microbial insecticide Bt is the material of choice since it alone among the materials available for treatment of tent caterpillars does not damage the natural enemy populations. Natural enemy populations are responsible for ending most caterpillar outbreaks. If they are damaged by treatments, outbreaks may continue for additional seasons. Among the materials commonly recommended in attempts to suppress tent caterpillar populations are: acephate, carbaryl, diazinon, dimilin, malathion, methoxychlor, and trichlorfon (see Hamel, 1981, Retnakaran et al. 1979). All these materials can cause mortality to natural enemies of tent caterpillars. Using mixtures of these or related materials with Bt defeats the purpose of using a selective agent like Bt since it incorporates an unselective component.

Bt currently is sold under the trade names: Thuricide® (Sandoz), Biotrol®, Dipel® (Abbott Laboratories), and Bactospeine® (Biochem). For a current research update on Bt consult Burges (1981). A comprehensive review article including history, mechanisms, taxonomy and use of Bt was prepared by Dubois and Lewis (1980).

Bt is a bacterial stomach poison and must be eaten to become toxic. The rod-shaped spore-forming gram positive bacterium produces a diamond-shaped protein crystal referred to as the delta-endotoxin. The spore stage and the protein crystal are contained within the same cell. When released from the cell and dissolved the crystal is toxic to many insects. The crystal is composed of aggregates of proteins which after ingestion by certain insects with highly alkaline (pH of 9+) guts and the appropriate enzymes, dissolves into toxic components. These toxic components (or endotoxins) block the enzyme systems that protect the caterpillar's gut from its own digestive juices. Within 10-15 minutes holes appear in the gut wall and the insect usually stops feeding. Bacterial spores then invade the insect's body cavity through these holes and produce a septicemia which kills the insect.

4. Management Alternatives-Chemical:

Table 4 compares commonly recomended chemical controls and the microbial control Bt. Bt effectively kills tent caterpillar populations selectively, is harmless to humans and degrades completely to non-toxic components. From a pest control viewpoint alone, the use of Bt against actively feeding larval stages rather than another material is superior because it does not directly damage the natural enemy populations. However where a large larval population is wandering on the ground, in or on buildings, or on roads or pathways, and where vacuuming alone will not remove them a short-lived contact insecticide may be useful. The material of choice in such a situation is a pyrethrum extract (frequently called pyrethrins as the extract is a mixture of active materials), or a synthetic pyrethroid with a high LD_{50}.

All pesticides are labeled for specific uses by the U. S. Environmental Protection Agency. All label instructions must be strictly followed.

Table 4.

A COMPARISON OF EFFICACY, SELECTIVITY, TOXICITY, AND FATE OF INSECTICIDES USED AGAINST TENT CATERPILLARS*

INSECTICIDE	EFFICACY**	SELECTIVITY	TOXICITY (LD_{50})	MOBILITY¶	COMMENTS
Acephate	H	L	M	M	
Bacillus thuringiensis	H	H	0	0	
Carbaryl	H	L	M	M	
Diazinon	H	L	M	M	
Malathion	H	L	L	M	mobility is an estimate
Methoxychlor	H	L	H	H	
Pyrethrins	H	L	L	L	
Trichlorfon	ND	L	M	M	mobility is an estimate

* Insecticides cited are from Agriculture Handbook 585 (Hamel, 1981) and other sources. Combinations of these insecticides are not considered in this comparison.

** KEY:

H = High; M= Medium; L= Low; 0= None or zero (e.g. not effective, non-selective, non-toxic, etc.).

For toxicity categories: H= LD_{50}'s of 1-99 mg/kg; M= 100-1000; L=>1000; based LD_{50} data from Wiswesser (1976).

ND= no data.

¶ Low mobility as used here means little or no residue since ability to move in food chains and abiotic environments is linked to stability of residues.

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NATIONAL PARK SERVICE
IPM Information Package

THISTLES

Final Report

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Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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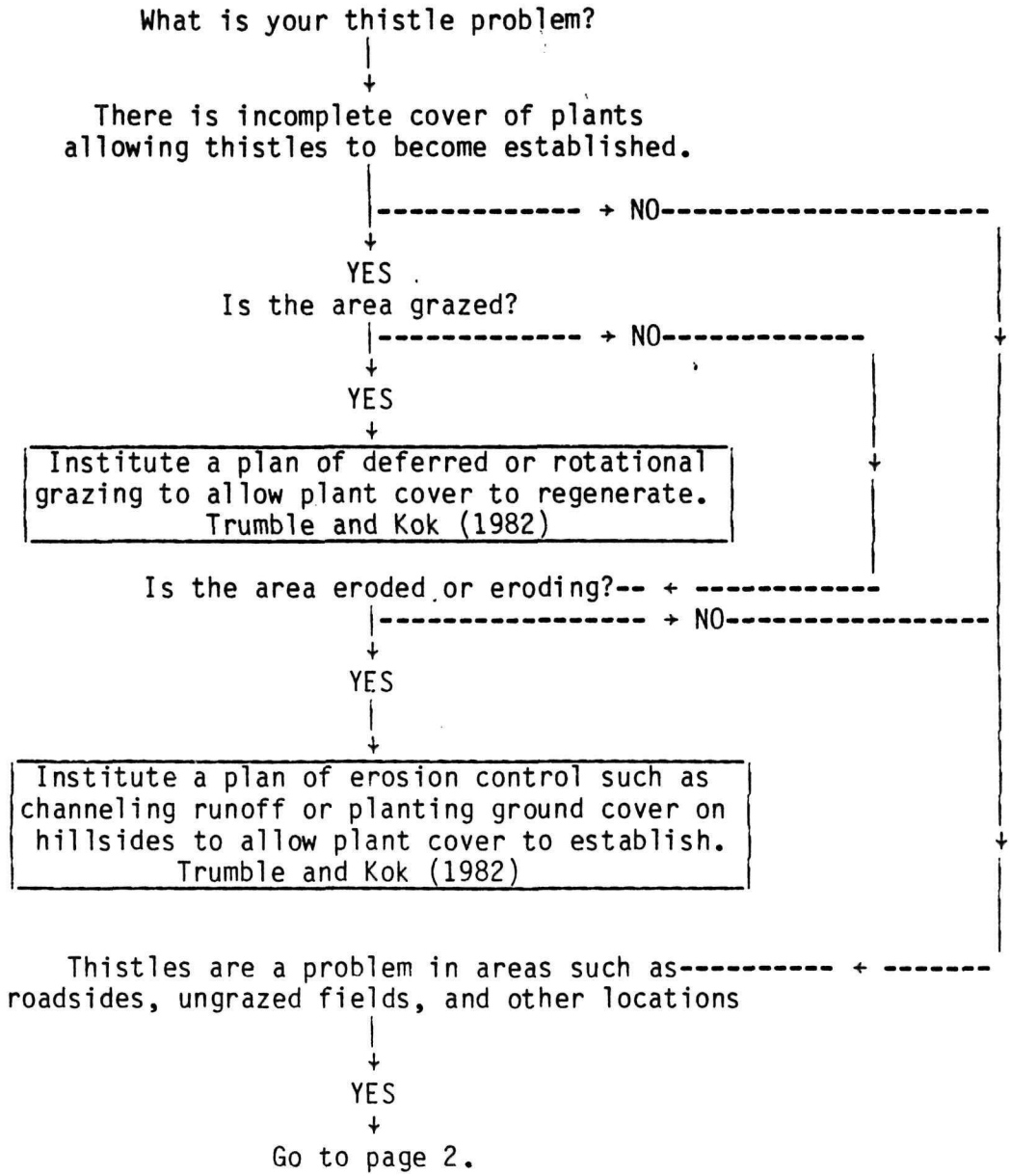
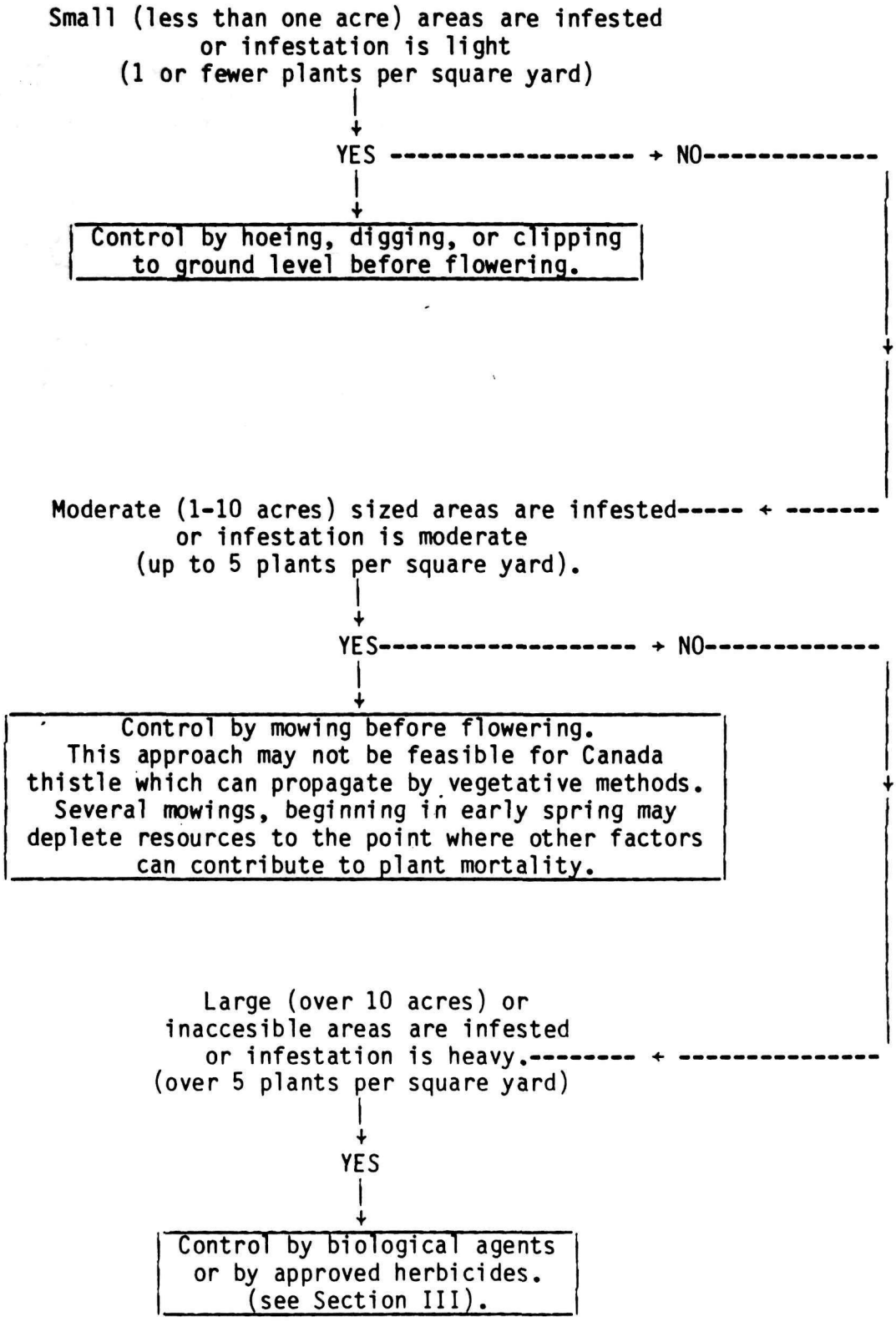
I. THISTLE IPM DESCISION TREE *

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



*Adapted from Trumble and Kok, 1982.


Small (less than one acre) areas are infested
or infestation is light
(1 or fewer plants per square yard)
YES
NO
Control by hoeing, digging, or clipping
to ground level before flowering.
Moderate (1-10 acres) sized areas are infested
or infestation is moderate
(up to 5 plants per square yard).
YES
NO
Control by mowing before flowering.
This approach may not be feasible for Canada
thistle which can propagate by vegetative methods.
Several mowings, beginning in early spring may
deplete resources to the point where other factors
can contribute to plant mortality.
Large (over 10 acres) or
inaccesible areas are infested
or infestation is heavy.
(over 5 plants per square yard)
YES
Control by biological agents
or by approved herbicides.
(see Section III).

II. THISTLE BIOLOGY AND ECOLOGY

1. Species Described:

Five species of thistle are currently considered major pest weed species by NPS and are under chemical, biological, or cultural control programs in North America.

Other species such as Carduus acanthiodes, (plumeless thistle), C. crispus, (welted thistle), and C. macrocephalus, (nodding thistle), may be pest weeds in local areas.

1. Musk thistle - Carduus thoermeri Weinmann Origionally thought to be C. nutans (L.). C. nutans is only found in small isolated pockets (S. Batra, pers. comm.). The musk thistles are a complex of several species and subspecies, the taxonomy of which is unclear. See McCarty and Lamp (1982), for details.
2. Italian thistle - Carduus pycnocephalus L.
3. Canada thistle - Cirsium arvense (L.)
4. Bull thistle - Cirsium vulgare (Savi)Tenore
5. Milk thistle - Silybum marianum (L.)

See Fernald (1950), pages 1538-1542, and Peterson & McKenny (1968), pages 302-306 for descriptive keys and illustrations of thistle species. See also Moore, R.J. and C. Frankton (1974), for detailed keys to species.

2. Geographic Distribution:

The species listed below were introduced from Europe and North Africa into North America.

1. Musk Thistle - Throughout U.S., especially common in Southern California, Midwestern, and Appalachian regions.
2. Italian Thistle - Califronia (mainly in coastal counties), also Midwest. Rare in other areas of U.S.
3. Canada Thistle - Throughout North America except Alaska. (Most common in northern tier of states and southern Canada.)
4. Bull Thistle - Southern Canada and throughout U.S.

5. Milk Thistle - California, (mainly in coastal counties and drier areas.

3. Habitat:

Thistles are pioneer species and are most often found in sites where the ground cover or grass cover have been disturbed by grazing, erosion, traffic, or other means. Each plant produces in excess of 10,000 seeds, (some produce as many as 120,000). The fine filaments or pappus (thistle down) of the seed coat permit windborne dispersal over long distances to suitable habitats. Reinfestation of areas occurs from waste places or roadsides where control is not practiced or by long-lived seeds from previous years.

Different species of thistle prefer different soil types:

1. The Carduus thistles on limestone and more fertile soils (Batra, 1982).

2. Bull thistle is predominant on sandy and clay soils.

3. Canada thistle on shale, sandstone or shist soils.

4. Life Cycles:

Thistles can be divided according to their life cycles in the following manner:

1. Summer annuals, which grow each spring or summer from seed. They grow, mature, produce seeds, and die in one growing season. Seeds generally overwinter before germinating the following spring. Summer annual thistles include Italian thistle.

2. Winter annuals, which germinate in late summer or fall from seed, then mature and produce seed the following spring or summer. Seeds are dormant during the spring. Winter annual thistles include milk thistle.

3. Biennials, which germinate at any time during the growing season. They usually produce a rosette of leaves close to the soil during the first season, then flower (using energy and nutrients stored during the first seasons growth), mature, and die during the next year. Biennial thistles include musk thistle which flowers in May-June, bull thistle which

flowers in July-September, and Italian and milk thistles which may be biennial in dry habitats.

4. Perennials, which become established by seed or vegetative parts (e.g., roots, tubers, or rhizomes). Once established, they live for more than 2 years, and often for many years. Perennial thistles include Canada thistle which flowers in June-October.

5. Seasonal Abundance:

Thistles exhibit foliar growth during the spring, summer, and fall. the amount of growth and rate of new establishment varies from region to region according to geographic, ecological, and climatic characteristics of each region.

6. Response to Environmental Factors:

Any site which is able to support thistle growth will eventually become colonized by species able to utilize available conditions.

Newly germinated thistle seeds require considerable light and usually become established on disturbed areas of pastures or croplands where competition is limited during the seedling stage. (Hodgson, 1968).

7. Impact of Thistles:

7.1 Direct Impact:

Thistles compete for light, water, and nutrients with other, more desireable species.

7.2 Indirect Impact:

Thistles reduce the use of an area for grazing or recreational purposes because of the prominent spines on leaves, stalks, and blooms. Livestock do not eat thistles, and will not graze between thistle plants on more desirable forage. (Batra, 1982).

8. Natural Enemies:

Pest species of thistles have been introduced into North America without their compliment of natural enemies. In Europe, Carduus thistles are attacked by approximately 340 species of insects and 7 fungal pathogens. Current research in biological control is an attempt to reunite natural enemy species with their hosts (see page XXXVI-7).

III. THISTLE MANAGEMENT

1. Population Monitoring Techniques:

Thistles are relatively conspicuous weeds and periodic visual inspections should be sufficient to monitor thistle populations in most cases.

The permanent plot technique is a good way to monitor thistle populations after they have become established and while they are being controlled. A representative section of the field is marked off and thistles are counted, mapped, and notes made on their condition (height, flowering, etc.). Monitor on a regular basis (weekly, biweekly, monthly). Keep careful records, note when treatments take place, or when biological controls are introduced (naturally or artificially). Study of records, over time, will show population trends and indicate whether or not control strategies are successfull.

A variation on the above is the use of photo plots. Take photographs of the sample plot showing the density of thistles and condition. Include in the photo an object of known size (person, domestic animal, or measuring stick) to indicate thistle size. Also include the date. This method is especially useful in monitoring the effects of control measures over the course of several seasons.

2. Threshold/ Action Population Levels:

Many states have laws requiring the control or removal of pest thistle species before they flower, whenever and wherever they occur. In these states, and in most other instances, the threshold action level is 1 or more weed thistles. The action level is therefore 1 or more weed thistles observed in an area.

Losses in cultivated crops are as high as 60% at usual levels of infestation (25 shoots of Canada thistle C. arvense per square yard). Pasture losses from Canada thistle at a density of less than 2 shoots per square meter are as high as 15%. (Hodgson, 1968).

3. Management Alternatives - Nonchemical:

Cultural Controls - In areas which are grazed, eroded, or subject to heavy traffic, the grass cover may not be dense enough to prevent establishment of thistles. Rotational or deferred grazing, water conservation, and erosion control, redirection of traffic, and sound pasture and turf management practices can reestablish heavy grass cover and prevent thistle establishment (Bendall, 1973; Trumble and Kok, 1982).

Grazing management can reduce thistle densities and prevent further invasions by limiting grazing in

spring and throughout the season to promote vigorous growth of perennial grasses and forbes. Early growth left ungrazed outcompetes thistles and lowers infestation levels. Areas left ungrazed in spring may be grazed later in the season.

Mechanical Controls - Cutting or removing thistles (where feasible) can be effective in reducing thistle populations. Musk thistle, if mowed within 2 days of flowering of the terminal blooms, will not produce seed or regenerate significantly. Timing in mowing is important; if mowing occurs 4 days after terminal bloom anthesis (full flowering), significant amounts of seed are produced. Since thistle stands mature at different times, careful monitoring and proper timing are necessary for mowing to be a viable option in an IPM program. However, even if mowing is done late and seed is produced, mowing the stalks will reduce seed dispersal and seed production, keeping infestations from spreading widely (McCarty & Hattling, 1975). Hodgson (1968), reports excellent control in alfalfa fields mowed for hay twice a year.

Canada thistle, due to its ability to propagate vegetatively, is difficult to control by mechanical methods. However, repeated cultivation can significantly reduce infestations if begun when plant reserves are at their lowest stage in early spring (early bud stage), before the shoot leaves can furnish energy to the roots in amounts greater than the roots require for production of new growth.

Cultivation should start in early spring by plowing and disking. When new shoots appear, the area should be cultivated 3-4 inches deep every 20-21 days to destroy new shoots. Up to 90% or more of a Canada thistle infestation can be eliminated in a single season of cultivation when properly performed. Remaining plants can be eliminated by continuing cultivation in the following spring (Hodgson, 1968).

Mechanical controls are compatible with biological controls if the mechanical controls are used early in the season to stress the plants, and allow natural enemies to enter the system to further weaken and eliminate thistles. Mechanical controls combined with chemicals may be successful in some cases. In most cases, however, combining a chemical and biological control is a more viable approach to thistle management.

Controlled burning, unless conducted on a regular basis, may only damage the aboveground portion of the thistle, allowing rapid regrowth from the root section.

Biological Control - Imported weed thistles have been the subject of biological control programs for several years.

Biological control agents seldom eliminate pest thistles from an area, but can reduce populations below set economic thresholds.

Rhinocyllus conicus, a European weevil which feeds on developing seed heads, has been introduced into the U.S. and Canada for control of Carduus thistles, particularly the musk thistle. It has also been introduced for control of Italian and milk thistles in the western U.S. In the absence of Carduus thistles, it will feed on Canada and bull thistles, but control is not as complete as on its primary hosts. R. conicus deposits eggs on bracts and flower stems. Larvae feed beneath developing seeds, destroying them. Pupation occurs in the flowers, and adults emerge in mid-summer. Adults hibernate in overwintering floral rosettes. There is one generation per year.

Trichosirocalus horridus, another European weevil, has also been introduced for control of Carduus thistles. This insect primarily feeds on the root crowns of musk and Italian thistles. T. horridus has been released in Canada and Virginia. It has not been introduced on the West Coast of the U.S. because it has been shown experimentally to feed on artichoke. However, it is not considered to be a pest in artichoke-producing areas of Europe, and further studies are being carried out. T. horridus deposits eggs on leaf ribs, and larvae migrate to the root crown where they feed. Pupation occurs in the soil. Adults feed on emergence, and overwinter in the rosettes. Weevils from populations in southern Europe and from central Europe have been introduced into the U.S. Southern European weevils mate in autumn, oviposit from mid-December to March, and adults emerge in April and June. Central European weevils mate in spring and oviposit in May to June. Adults emerge in September and hibernate until the spring thaw. These two populations (biotypes) are currently undergoing further study to develop more effective control for thistles.

The Cirsium thistles (Canada and bull thistles) are under continuing study for biological controls.

Altica carduorum, a European weevil has been imported into North America for control of Canada thistle. Adults feed throughout the summer on leaves, defoliating the plant, and weakening it. Although Canada thistle is seldom killed outright by this weevil, the continued stress upon it reduces the number and vigor of vegetative shoots and reduces seed production. Although repeatedly released in North America, this species is not yet well established (Batra et al., 1981).

A second weevil, Ceuthorhynchus litura, which feeds on leaves and root crowns is established and providing some control in Canada, Idaho, Montana, and California.

A Tephritid fly, Urophora cardui, which feeds on Canada and bull thistles, was released in 1973 and is established in British Colombia.

Cassida rubiginosa, a Chrysomelid beetle which feeds on leaves of Carduus and Cirsium thistles, has been adventively established in North America since 1927 (Batra et al., 1981).

Several other species of insects, mostly seed-head weevils, are currently being studied for possible importation and release for biological control of thistles in the U.S.

Two fungal pathogens which are spread by thistle feeding insects are also being considered for release in the U.S.:

Rust fungi in the genus Puccinia which attack the leaves of the basal rosette and underground basal parts have been introduced into Canada. Further studies are required to determine their effectiveness.

Ustilago cardui, a smut fungus, has been observed to attack late maturing seed heads of Carduus thistles in Europe. Seed production is stopped in infected plants, giving full control. This fungus compliments control by R. conicus which feeds on early flower heads (Bolt 1978).

Consult your NPS Regional or WASO IPM Coordinator for further information on biological control for thistles in your area.

4. Management Alternatives - Chemical:

The following herbicides have been used by NPS to control thistles:

Atrazine
2,4-D
Glyphosate
Dicamba

Spot treatments, rather than broadcast, are preferred. Control must be initiated before the plants blossom and produce seeds. Young plants are most susceptible to control with chemicals. Best results are obtained when plants are in their initial and heaviest growth stage.

Trials combining herbicides (usually 2,4-D), and biological control agents (R. conicus and T. horridus) have shown the two to be compatible if precautions are taken (Trumble and Kok, 1980). Field and laboratory tests have shown that spring application of 2,4-D (when blooms are beginning) provides the most effective thistle control, and causes the fewest adverse effects on thistle weevils; R. conicus adults and T. horridus pupae, the only life stages likely to be exposed to such spraying, are relatively unaffected by the herbicides. Adults of both species will move to unsprayed plants, thus increasing biological control in nearby areas where herbicide treatment is not feasible or economical.

Glyphosate is recommended when selectivity is not requried or where it can be used in a manner that does not affect neighboring non-target plants. Where selectivity is required, 2,4-D or dicamba are recommended. Tests to determine compatibility of biological control agents with herbicides other than 2,4-D are still in the planning stage.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Use cultural controls to reestablish dense grass or ground cover in order to prevent or reduce thistle establishment.

2. Cut, mow or otherwise remove thistles, if feasible. Thistles should be cut before the flowering of terminal blooms to prevent seed production.

3. Use biological controls, if possible, in your area. Check with Regional or WASO IPM Coordinator for details.

4. Use appropriate herbicides on a spot treatment basis. Time applications to control thistles at prebloom stage and for compatibility with natural enemies.

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NATIONAL PARK SERVICE
IPM Information Package

TICKS

Final Report

27 July 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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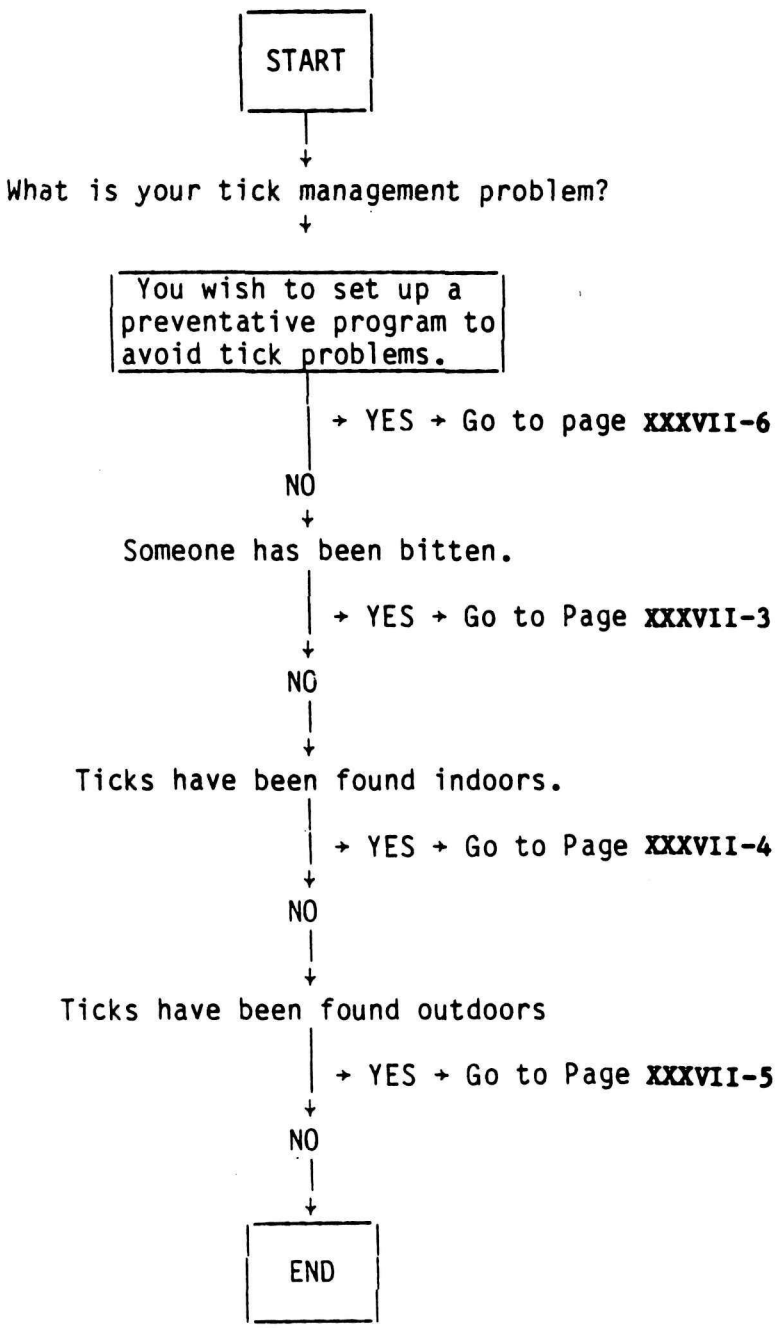
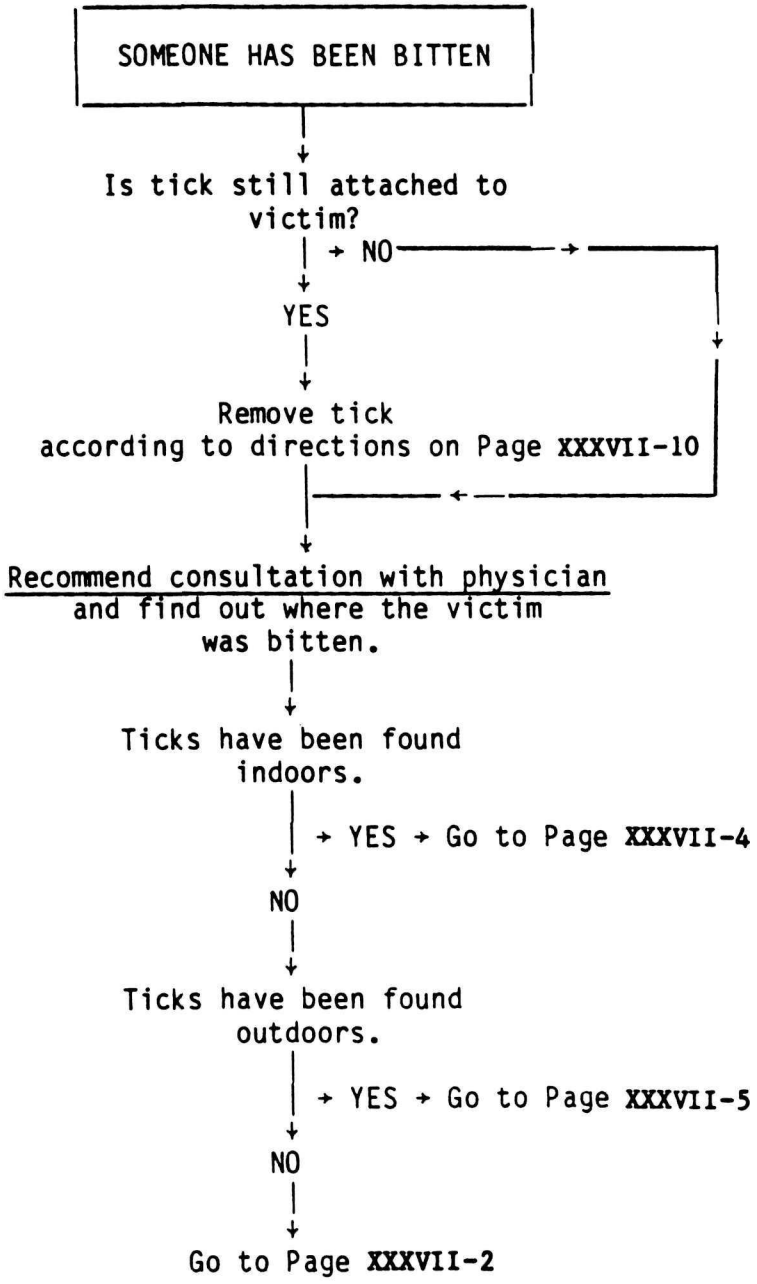
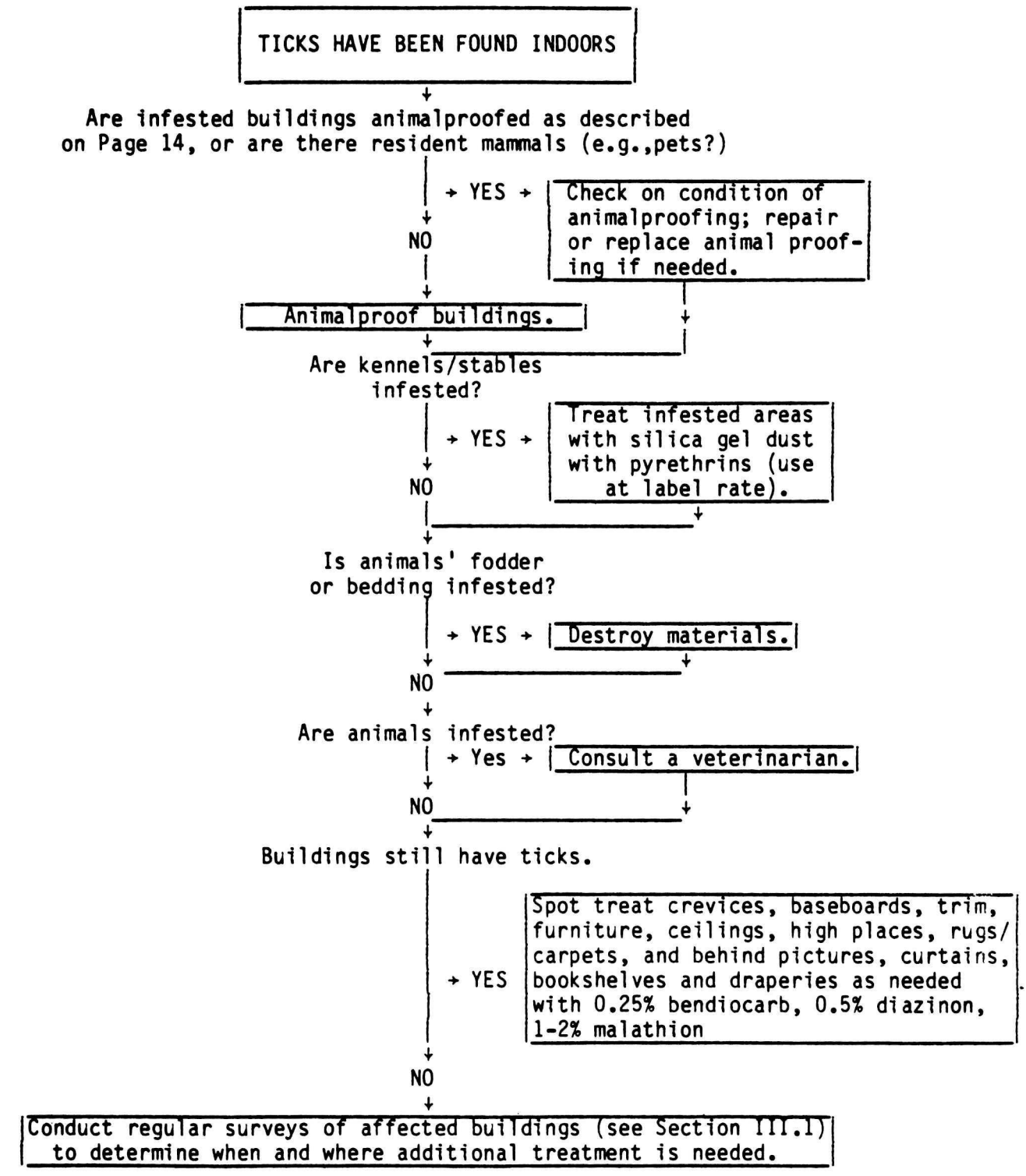
I. TICK IPM DECISION TREE

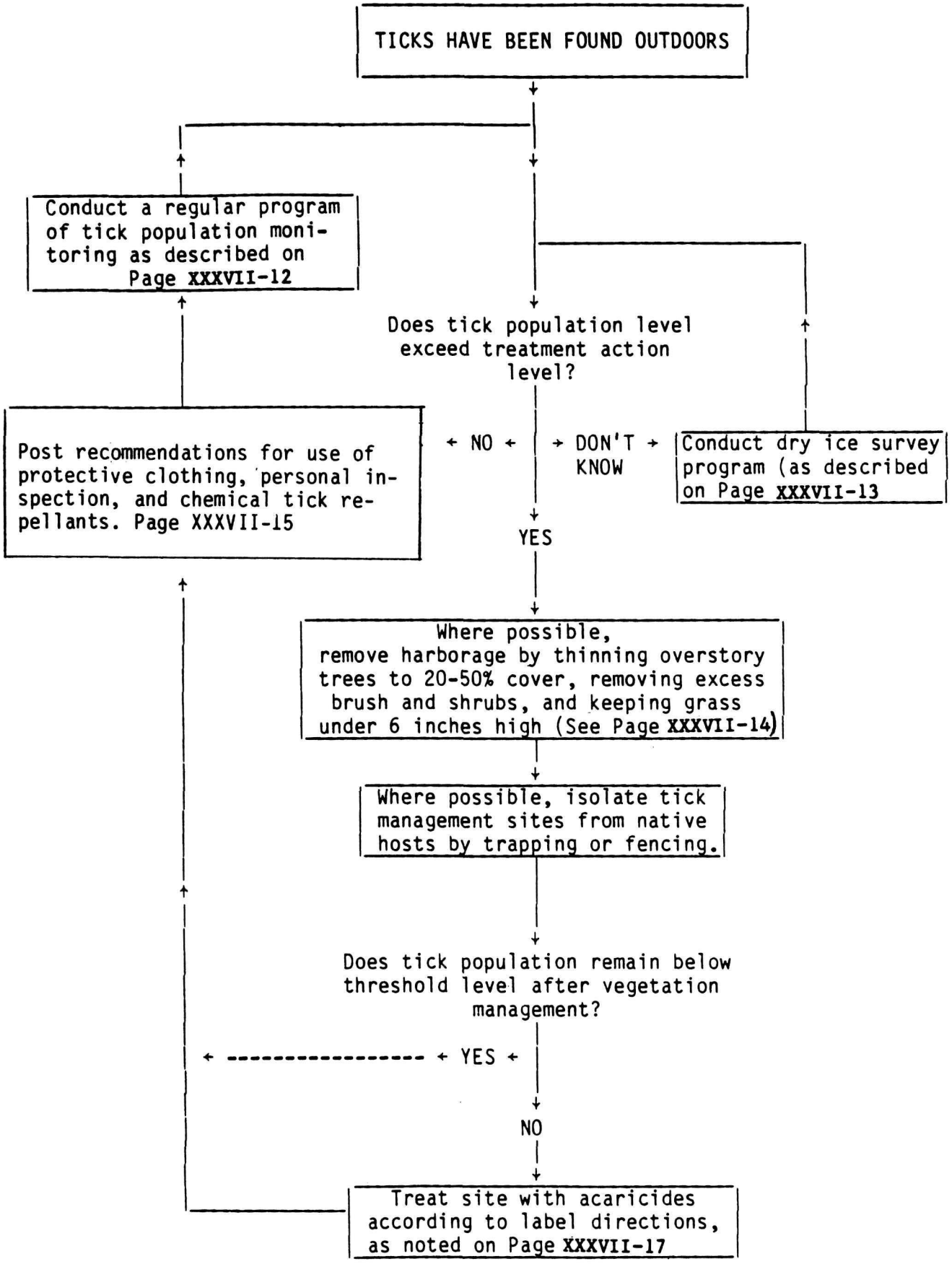
These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.

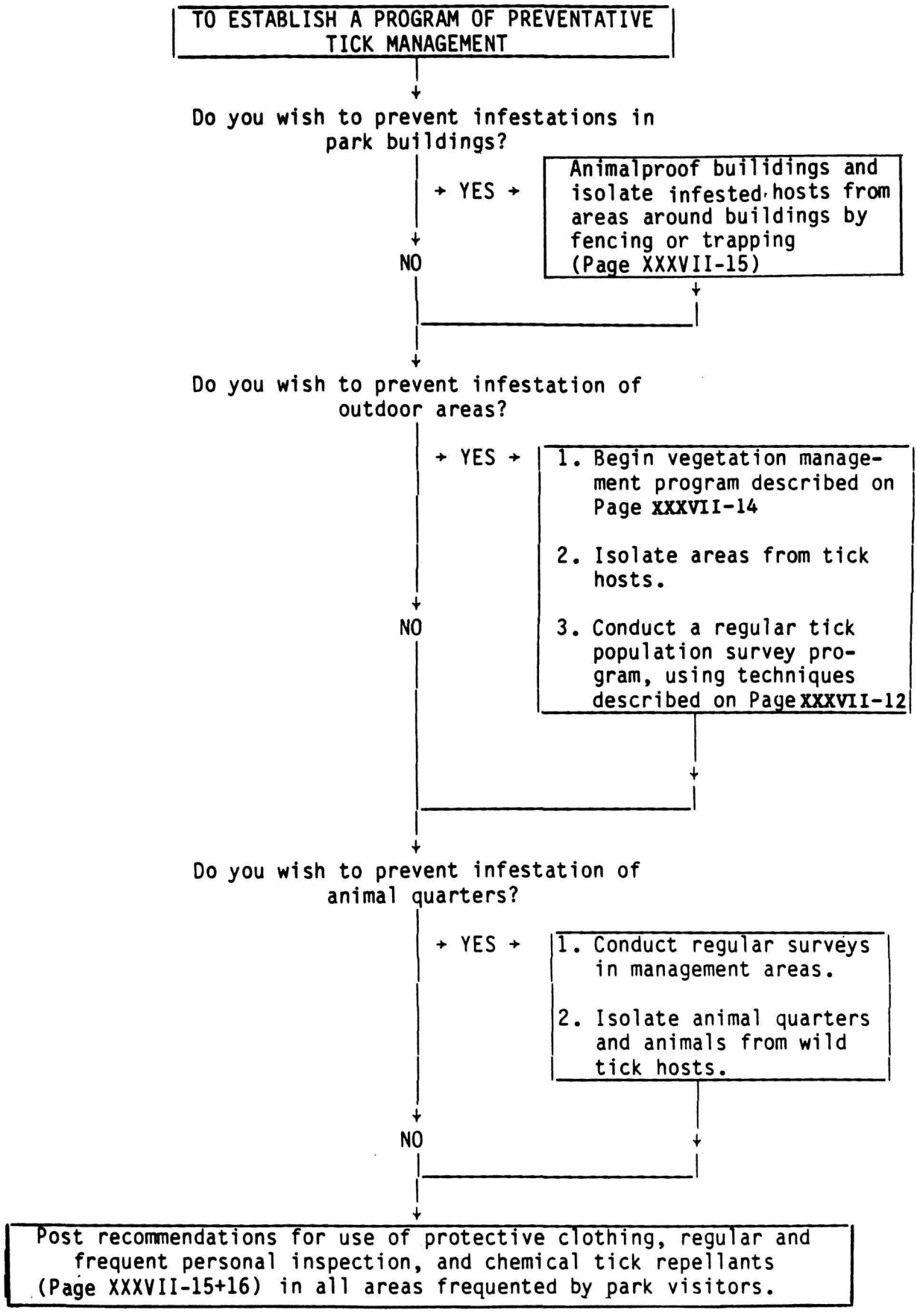



SOMEONE HAS BEEN BITTEN
Is tick still attached to victim?
NO
YES
Remove tick according to directions on Page XXXVII-10
Recommend consultation with physician and find out where the victim was bitten.
Ticks have been found indoors.
YES
Go to Page XXXVII-4
NO
Ticks have been found outdoors.
YES
Go to Page XXXVII-5
NO
Go to Page XXXVII-2



*From A. Mallis, ed. Handbook of Pest Control, 2nd. Ed. 1982.
**Bendiocarb is registered for use by certified applicators only.


TICKS HAVE BEEN FOUND OUTDOORS
Conduct a regular program of tick population monitoring as described on Page XXXVII-12
Does tick population level exceed treatment action level?
Post recommendations for use of protective clothing, personal inspection, and chemical tick repellants. Page XXXVII-15
NO
DON'T KNOW
Conduct dry ice survey program (as described on Page XXXVII-13
YES
Where possible, remove harborage by thinning overstory trees to 20-50% cover, removing excess brush and shrubs, and keeping grass under 6 inches high (See Page XXXVII-14)
Where possible, isolate tick management sites from native hosts by trapping or fencing.
Does tick population remain below threshold level after vegetation management?
YES
NO
Treat site with acaricides according to label directions, as noted on Page XXXVII-17


TO ESTABLISH A PROGRAM OF PREVENTATIVE TICK MANAGEMENT
Do you wish to prevent infestations in park buildings?
YES
Animalproof buildings and isolate infested hosts from areas around buildings by fencing or trapping (Page XXXVII-15)
NO
Do you wish to prevent infestation of outdoor areas?
YES
1. Begin vegetation management program described on Page XXXVII-14
2. Isolate areas from tick hosts.
3. Conduct a regular tick population survey program, using techniques described on Page XXXVII-12
NO
Do you wish to prevent infestation of animal quarters?
YES
1. Conduct regular surveys in management areas.
2. Isolate animal quarters and animals from wild tick hosts.
NO
Post recommendations for use of protective clothing, regular and frequent personal inspection, and chemical tick repellants (Page XXXVII-15+16) in all areas frequented by park visitors.

II. BIOLOGY AND ECOLOGY OF TICKS

1. **Species Described:**

   A. Lone Star Tick - *Amblyomma americanum* L .

   B. American Dog Tick - *Dermacentor variabilis* Say

   C. Rocky Mountain Wood Tick - *Dermacentor andersoni* Stiles.

   See U.S. Department of Health, Education, and Welfare (1967), page 40, for a comparative key to important tick species.

2. **Geographic Distribution:**

   A. Lone Star Tick - Texas, Oklahoma, Misouri, Arkansas, Louisiana, Mississippi, Alabama, Tennessee, Kentucky, Illinois, Indiana, Ohio, West Virginia, Virginia, Maryland, Delaware, New Jersey, South Carolina, North Carolina, Georgia, Florida. May also occur in New England States.

   B. American Dog Tick - East of Rocky Mountains, and in California, Oregon, Indiana, and West Virginia.

   C. Rocky Mountain Wood Tick - Widely distributed throughout the United States and Canada.

3. **Habitat:**

   A. Lone Star Tick - Wooded areas, especially where there is dense underbrush. Also found in scrub, meadow-margins, hedge rows, cane breaks, and marginal vegetation along rivers and streams.

   B. American Dog Tick - Wooded areas, abandoned fields, medium-height grasses and shrubs between wetlands and woods, and sunny or open areas around woods.

   C. Rocky Mountain Wood Tick - Fields and forested areas.

4. **Hosts:**

   Ticks are blood feeders on many species of mammals including humans. While adults generally feed on large hosts, larvae and nymphs are more likely to feed on small hosts. The Lone Star Tick also feeds on many birds.

5. **Life Cycle:**

   A. Lone Star Tick - Eggs are deposited in middle to late spring under leaf and soil litter. Incubation may take 30 days or longer, depending on the temperature. Newly hatched larvae feed within five days after hatching, and remain attached to their host for 3-7 days. After feeding, larvae fall from their hosts, and hide in vegetation. Molting occurs between 9 and 27 days after feeding. Newly molted nymphs attach

to a second host within 9-27 days. Nymphal feeding may last 38 days, and is followed by a 13-46 day resting period before the second molt. Newly molted adults attach to a third host after 3-10 days, and feed for 6-24 days. Oviposition occurs 7-16 days after the last blood meal; a single female may produce 8,000-10,000 eggs over 9-28 days. Males die after mating (after the final blood meal). The complete life cycle requires about 2 years.

B. American Dog Tick - Over 14 to 32 days, the female lays masses of 4,000 to 6,500 ellipsoidal, yellowish-brown eggs, and then dies. The eggs normally hatch in 36 to 57 days. The unfed larvae crawl about, seeking hosts, and can live for more than a year (540 days maximum) without food. In a simulated meadow, larvae became engorged on mice in an average of 4.4 days, then dropped from their hosts seeking protected places to molt. The nymphs crawled about seeking hosts. The engorging period ranged from 3 to 11 days; the greatest number dropped on the sixth day, and found protected places in which to molt. They molted after 3 weeks to several months. Nymphs also could live for more than a year without food; the maximum period was 584 days (Metcalfe and Flint, 1962).

Unengorged adults may live for more than 2 years if they do not attack to animals. The engorgement of females requires 5 to 13 days, and mating takes place on the host. In the absence of suitable hosts, the life cycle of the American dog tick may last 4 or more years. Under favorable conditions, the life cycle may last only 3 months.

C. Rocky Mountain Wood Tick - Females lay eggs in plant debris on the soil or in crevices in construction materials, usually in masses of hundreds at a single location. Eggs hatch into six-legged larvae ("seed ticks") that attach themselves to host animals and feed on blood. After the blood meal, the larvae generally drop to the ground to molt and become eight-legged nymphs. Nymphs take another blood meal (from different host species), and develop into mature adults. Wandering males frequently mate with feeding females. Mated females take another blood meal before producing eggs. Ticks characteristically become greatly enlarged on feeding (engorgement).

If the larva, nymph, or adult does not find a suitable host, it survives for extended periods without feeding (or molting). A single life cycle may last 3 years or more.

6. Seasonal Abundance:

A. Lone Star Ticks - Abundance of lone star ticks in Oklahoma has been documented by Hair and Howell (1968):

-larvae are most active from mid-June through mid-November,

-nymphs are active from mid-March through mid-October, and

-adults are active from mid-March through August, and may appear from December to mid-February.

B. American Dog Tick -Newhouse (1983) found adult ticks active in Georgia forests from March to September. Population peaks occurred during the first and last weeks of May, and the last week of June. Adults are most active in New York from mid-April to mid-July.

C. Rocky Mountain Wood Tick - Adults and nymphs can be found from late March to late summer, and feed from mid-March to mid-July. No additional information was available.

7. Responses to Environmental Factors:

A. Lone Star Tick - Tick abundance is dependent on high relative humidity, high soil moisture, and low daytime temperatures in woody areas (Mount, 1981).

B. American Dog Tick - Newhouse (1983) found that high light intensity or low relative humidity stimulates questing behavior.

C. Rocky Mountain Wood Tick - This tick has been associated with cool soil temperatures, shallow soil, abundant leaf litter, and high relative humidity.

All of these species are attracted to carbon dioxide (CO_2), and generally prefer low light intensity and high relative humidity.

8. Medical Importance: These ticks are important because their attachment and blood-feeding can be dangerous to humans.

8.1 Direct Effects: All species may cause tick paralysis if they feed at the base of the victim's skull for extended periods. Symptoms include paralysis of the arms and legs, followed by a general paralysis which can cause death. The victim can recover completely in a few hours, after the tick is removed. Tick paralysis is mainly reported in the western U.S., but may occur whereever ticks are found. See TICK REMOVAL, below (8.3).

8.2 Indirect Effects:

A. Lone Star Ticks - The lone star tick is a potential vector of Rocky Mountain spotted fever(RMSF), tularemia, Bullis fever, the lone star virus, and Q fever.

B. American Dog Tick - The American dog tick is a vector of RMSF, St. Louis encephalitis, and tularemia.

C. Rocky Mountain Wood Tick - This species is a vector of RMSF, Colorado tick fever, tularemia, and Q fever.

The most important disease carried by these ticks is RMSF. The most characteristic symptom of RMSF is a rash on the ankles, wrists, and forehead 1-2 weeks after the victim is bitten. The rash spreads to the trunk, and is accompanied by chills, fever, and prostration. RMSF is transmitted after the tick feeds for several hours. If the tick is removed promptly, there is a smaller chance that RMSF will be transmitted.

8.3 Tick Removal: The best means to prevent the transmission of tick-borne diseases and the development of tick paralysis is prompt removal of ticks. This requires regular inspection of clothing and exposed skin for attached ticks (unattached ticks may easily be picked off without risk). To remove a tick, grasp it crosswise with narrow tweezers (do not crush or rupture the tick) as close to the point of attachment as possible. Cover it with tissue or gauze, and retract or pull tick firmly in the direction of attachment. Do not rotate the tick; some back-and-forth wiggling may be necessary. Removed ticks should be immersed in alcohol to kill them. The skin should be washed thoroughly with soap and water.

8.4 Outbreaks of Tick-borne Diseases: The diseases listed in Section 8.1 can be fatal. Any case of such a disease should be reported to medical authorities immediately. Frequent or multiple reports of tick-borne diseases should be reported to a NPS Public Health Service Representative. The representative can recommend actions to control disease outbreaks. Closing affected park areas may be advisable during such periods.

9. Natural Enemies: Several species of ants are known to feed on ticks.

III. TICK MANAGEMENT

1. Population Monitoring Techniques:

A. Lone Star Tick - Periodic surveys of potential or known tick habitats can reveal the presence of low-level tick infestations, and permit the application of management procedures to prevent or retard further population increase. A number of monitoring techniques have proven effective (Gladney 1978), including:

1. Examination of small animal hosts trapped at selected sampling sites - Live-trapped rodents may be placed in wide-mouth jars containing chloroform-saturated cotton. As soon as an animal dies, it should be removed, placed in a plastic bag, and cooled in an ice chest. Cooled animals should be shaken in 50% ethanol to kill attached ticks. Some ticks may remain attached to the animal, and must be picked off. Others may be found in the ethanol, and still others will have become dislodged in the plastic storage bag. All must be counted and identified. Larger animals may be anesthetized, visually inspected, and released. Since ticks begin to leave a dead body after a few hours, frequent visits to trap sites are required to ensure that trapped animals remain alive for sampling.

2. Examination of personnel for attached ticks - A volunteer wearing protective clothing walks through each sample site, and is then inspected. Ticks attached to or walking on the worker's clothing or skin are collected in 70% ethanol for later counting and identification. Careful inspection is necessary to prevent attachment of unnoticed ticks and possible disease transmission to the collector.

3. Dragging - A commonly-used method of off-host sampling involves dragging a white cloth over the ground or foliage where ticks are questing for passing hosts. Ticks cling to the cloth, and can be removed for counting and identification. An easily-constructed "drag" consists of a 3' x 4' sheet of white muslin, hemmed on all edges, weighted at one end, and attached to a wooden pole at the other end. A rope attached to each end of the pole allows the apparatus to be dragged across the desired sampling site. Several useful drag techniques are described by Gladney (1978). Selection of the sites to be sampled may have great effects on the efficiency of collection; lone star ticks are likely to be found in shaded areas of high humidity, while American dog ticks are most often encountered along roadways and animals runs. Sample sites should represent favored tick habitats (see

Page XXXVII-7) and sampling should be done under conditions favoring tick presence (e.g., when vegetation is not wet, and when temperatures are above 50°F).

4. Dry Ice Collection - This technique is nondestructive to small animals, requires no human "attractants", and appears to give more reproducible results than the drag technique. Ticks are collected on a cloth or plastic panel (Garcia, 1965; Mount and Dunn, 1983) containing a piece of dry ice, or on a special ly constructed wood or plastic trap (Gladney 1978) containing dry ice, which is placed for a predeter mined period in a selected sampling area. (Dry ice is available from most beverage and ice cream stores.) A simple technique used by Mount and Dunn (1983) involves placing a 0.5 lb block of dry ice in the center of a 2 x 3 foot panel of white polyester cloth on the ground at the chosen sampling site. After one hour, ticks on the top side of the panel are collected and/ or counted. See Gladney (1978) for descriptions of several other effective techniques.

   Sampling sites should be selected in areas favoring ticks and/or which are likely to receive heavy visitation. A conscientious monitoring program is the basis of effective IPM. Regular surveys should be conducted at all sites where ticks have been reported by park staff or visitors, and at other locations which appear to be favorable tick habitats. Accurate and complete records of sample sites and methods must be kept, so that the progress of tick populations and the effect of control measures can be gauged. A sample monitoring form is presented on page XXXVII-14

2. Threshold/Action Population Level:

A. Lone Star Tick - Mount and Dunn (1983) have recommended a threshold level based on sampling by means of the CO2 technique described above. A count of 0.65 ticks per 1 hour CO2 exposure is considered the economic threshold for general use in lone star tick management (equivalent to 1 tick per visitor per day). This value may not be applicable to your particular park situation. A level can be established by conducting regular CO2 surveys, and plotting the tick counts against the numbers of tick-bite complaints received. This will permit the selection of a complaint threshold level for each site surveyed. Treatment should be conducted to keep tick populations below the selected threshold; a lower ("action") level should be selected to trigger treatment programs.

B. American Dog Tick - See 2.A. Lone Star Tick.

C. Rocky Mountain Wood Tick - See 2.A. Lone Star Tick.

3. Management Alternatives - Nonchemical:

A. Lone Star Tick

1. Outdoor Areas

Dense shrub or tree cover or tall grass provides harborage for animal hosts of ticks, and protects ticks from losing body fluids by preventing exposure to drying winds and direct sunlight. Removal of excess brush and shrubbery, and clearing of overstory trees so that between 50% and 80% of a management area is exposed to direct sunlight at any time, are recommended control practices for forested areas, walkways, parks, and landscaped grounds (Hair and Howell 1968). Grass should not be allowed to grow more than 6 inches high, to allow ventiliation and illumination of soil. Hoch et al. (1971) noted that chemical tick control was rarely needed when vegetation control was practiced. Mount (1981) obtained 76, 78, 84, and 93% control (of adult males, adult females, larvae, and nymphs, respectively), using these techniques. Visitor activities should be directed to areas unfavorable for tick habitat.

Inspection of management sites should be performed regularly to determine when application of management techniques should be conducted. Several methods of sampling outdoor sites are available, including cloth drags, trapping surveys of animal hosts, and collection methods utilizing CO2 as an attractant (See Page XXXVII-12).

2. Animal Protection

Basic principles of animal tick management include 1) isolation of susceptible animals from known tick populations, and 2) rotation of pasture or run areas, to reduce tick populations.

3. Indoor Management

The major methods of nonchemical indoor tick management include regular inspection, elimination of animal harborage areas, use of food and wastehandling procedures which will minimize animal harborage and entry, and animalproofing of each building. This includes sealing all holes in foundations and walls, and screening (with heavy-gauge metal screen) aboveground windows, vents, and other openings (smaller than 1/4 inch wide) through which animals may enter.

4. Personal Protection

Recommended practices include frequent examination of clothing (preferably by another individual) and the body (after showering), destruction of collected ticks, and the wearing of protective clothing (including high-top shoes or socks pulled over trouser cuffs, and long sleeved shirts or jackets).

5. Surveys

Periodic surveys of potential or known habitats can reveal the presence of low-level tick infestations, thus indicating the need for application of management procedures to prevent or retard further population increase. See Page 11 for useful survey techniques.

B. American Dog Tick - See 3.A. Lone Star Ticks for management techniques likely to be effective against this pest.

C. Rocky Mountain Wood Tick - See 3.A. Lone Star Ticks for management techniques likely to be effective against this pest.

4. Management Alternatives-Chemical:

A. Lone Star Tick

1. Outdoor Areas

a. Insecticide/Acaricides.--Several compounds have been shown to provide effective control of tick populations in wooded areas, fields, and other outdoor sites; these include tetrachlorovinphos, fenthion, propoxur, and sumithion. Consult your regional IPM Coordinator to determine which pesticide, if any, is best suited to your tick control program.

b. Herbicides.--Herbicides have been suggested for use in brush, shrub, and overstory growth management, to eliminate harborages for animal hosts of ticks, and reduce humidity and shade which protect ticks from dessication in their habitats.

2. Protection of Personnel

Schreck et al. (1980) reported that application of the tick repellent chemicals DEET, M-1960 (a military formula) and permethrin provided good protection (81, 95, and 89%, respectively) against the lone star tick. DEET and M-1960 were found to be irritating to wear, and have disagreeable odors. Mount and Snoddy (1983) showed that application of pressurized sprays of 20% DEET to the exterior surfaces of clothing provided 85% protection against the Lone Star Tick (adults and nymphs) and 94% protection against the adult American Dog Ticks. They found that sprays of 0.5% permethrin gave 100% protection against both species; however, permethrin is not currently registered for either use so cannot be recommended at this time. DEET is available in several commercial products (e.g. Off, 6-12, Cutter's Insect Repellent). M-1960 is a mixture of the following:

30% N-butyl acetanilide;
30% 2-Butyl-2-ethyl-1,3-propanediol;
30% Benzyl benzoate; and
10% Tween 80 (an emulsifier).

3. Indoor Areas

Sites such as crevices; basebords; trimming; furniture; ceilings, high places; floors/carpets; behind pictures, bookshelves and drapes should be spot-treated (as needed) with:

0.25% bendiocarb, or
0.50% diazinon, or
1-2 % malathion (Mallis, 1982).

Fumigation may be successful in indoor sites; however, available fumigants are very dangerous, and must be applied by a certified applicator (as must bendiocarb sprays for spot treatments).

B. American Dog Tick - Little information regarding the control of D. variabilis is available. Koch and Burkwhat (1983) reported that propoxur and bendiocarb were the most effective pesticides against nymphs in laboratory studies; no field tests have been reported. See 4.A. Lone Star Ticks for management techniques likely to be effective against this pest.

C. Rocky Mountain Wood Tick - See 4.A Lone Star Tick for potentially useful control procedures.

5. Summary of Management Recommendations:

A. Lone-Star Tick- For tick management in outdoor areas, habitat reduction by removal of excess brush, clearance of dense overstory cover, and regular mowing of grassy areas to 6 inches or less in height is recommended. Regular CO_2 surveys of likely tick habitats will indicate locations where treatment is necessary. If nonchemical measures prove ineffective, registered herbicides (for habitat modification) and acaricides (such as chlorpyrifos or fenthion, for reduction of heavy infestations) may be needed during the first years of the program.

Animalproofing of park buildings (following chemical treatment of existing infestations) should eliminate habitats for tick hosts, reducing the chance of future infestations.

Recommended procedures for protection of park personnel and visitors include frequent examination of

the clothing and body of any person travelling in tick habitats, the wearing of protective clothing, and the use of clothing and/or skin-applied tick repellants.

Information should be made available to park visitors concerning:

- Known tick habitats within the park;
- Personal protection techniques (protective clothing, tick repellants);
- Tick removal techniques.

B. American Dog Tick- See 5.A. Lone-Star Tick.

C. Rocky Mountain Wood Tick- See 5.A. Lone-Star Tick.

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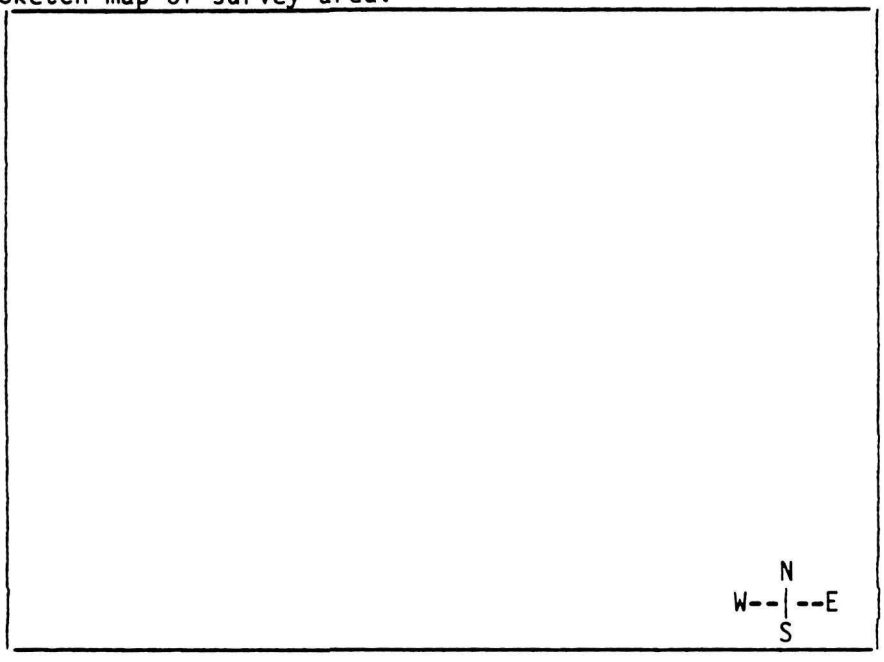
United States Department of Health, Education and Welfare. 1967. Pictorial keys to arthropods, reptiles, birds and mammals of public health significance. U.S. Dept. of Health, Education and Welfare, Washington, D.C. 192 pp.

V. SAMPLE TICK MONITORING FORM

Date:_____ Area:_____ Recorded by:_____

Sketch map of survey area:



- Show area dragged or placement of dry ice traps.
- Include any areas considered important, such as camping, picnic, trail areas, etc.
- Indicate type of survey conducted (check one):
  ___ Personal Examination
  ___ Host Animal Trapping
  ___ Drag Count
  ___ Dry Ice Trapping

Survey results:

1. Details of method (length of drag path, duration of CO_2 trapping, size of cloth, etc.):

2. Tick count:

Species	Lone Star Tick	American Dog Tick	Rocky Mt Wood Tick
# Larvae			
# Nymphs			
# Adults			

3. Proposed treatment:

4. Date treated:_____ Treated by:_____

5. Comments:

NATIONAL PARK SERVICE
IPM Information Package

TURFGRASS FUNGUS DISEASES

Final Report

27 August 1985

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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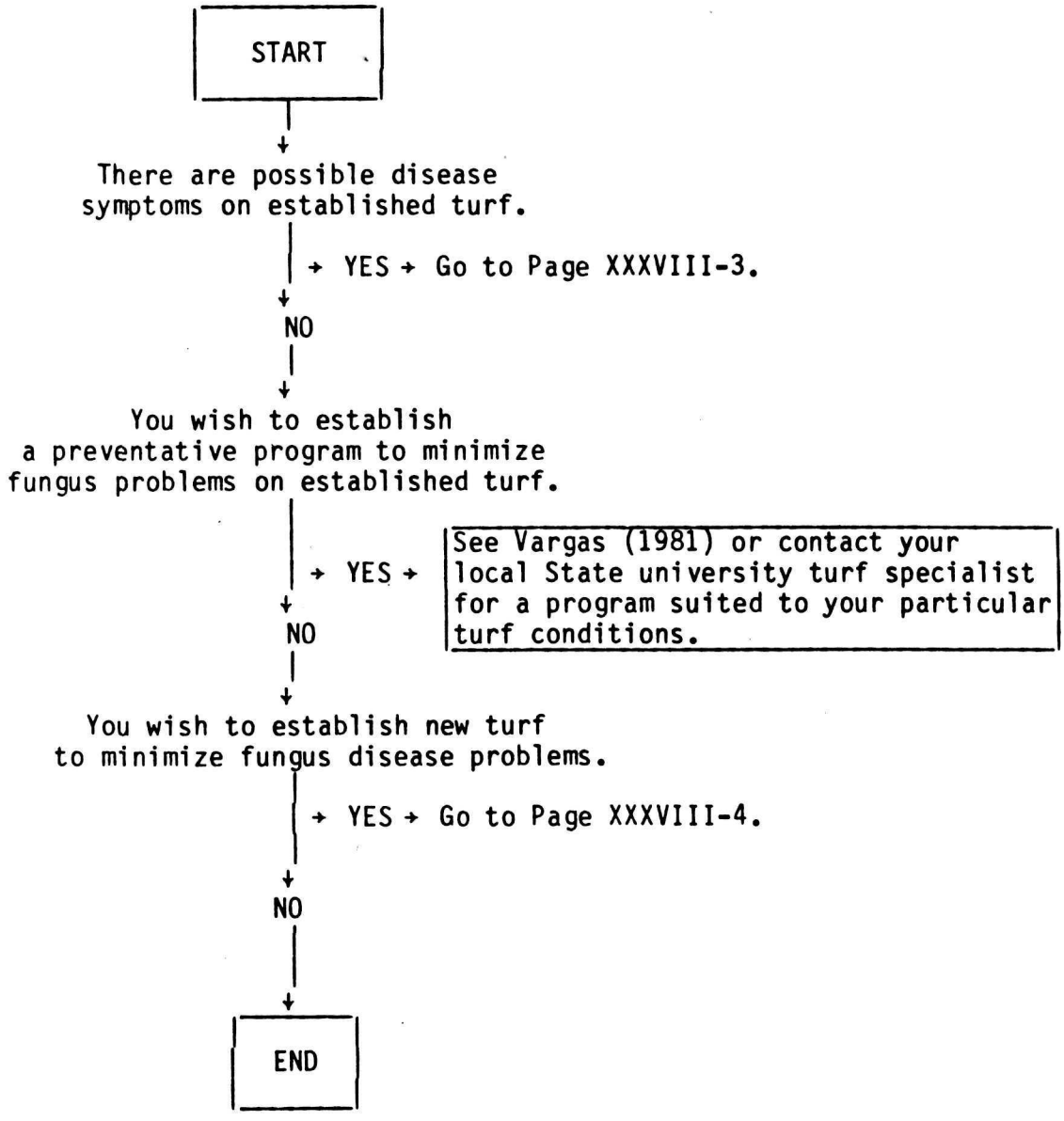
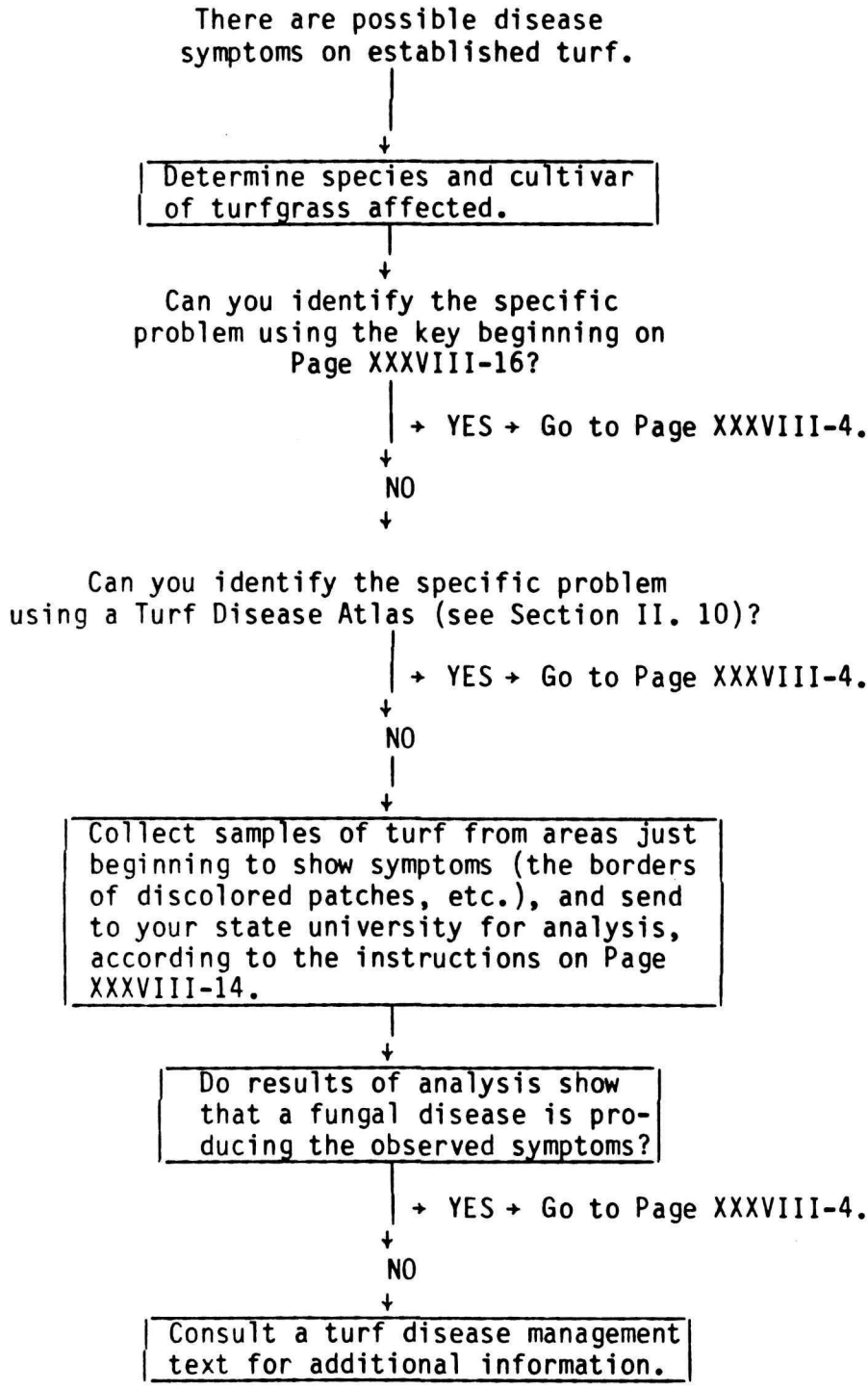
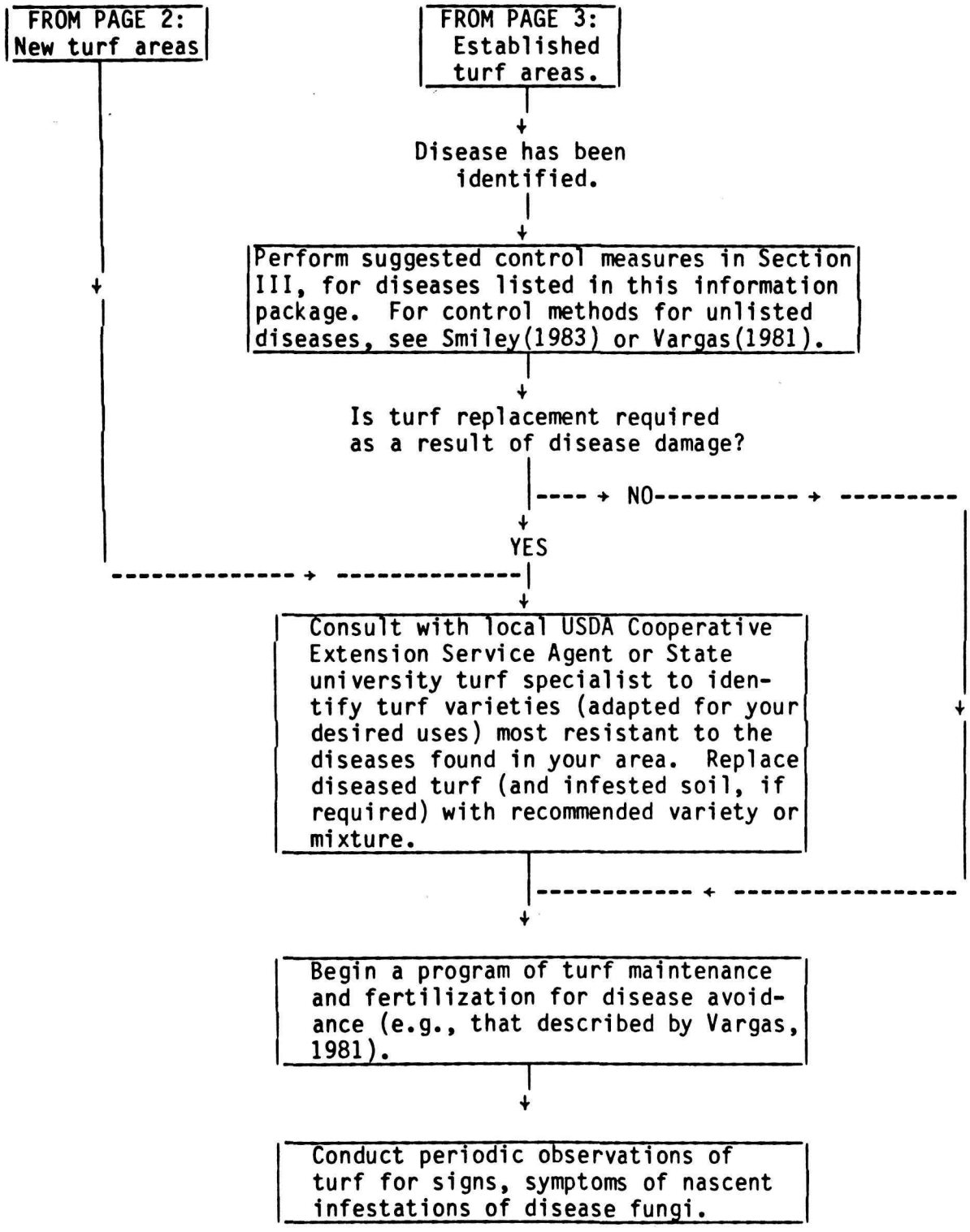
I. TURFGRASS FUNGUS DISEASE IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




There are possible disease symptoms on established turf.
Determine species and cultivar of turfgrass affected.
Can you identify the specific problem using the key beginning on Page XXXVIII-16?
YES → Go to Page XXXVIII-4.
NO
Can you identify the specific problem using a Turf Disease Atlas (see Section II. 10)?
YES → Go to Page XXXVIII-4.
NO
Collect samples of turf from areas just beginning to show symptoms (the borders of discolored patches, etc.), and send to your state university for analysis, according to the instructions on Page XXXVIII-14.
Do results of analysis show that a fungal disease is producing the observed symptoms?
YES → Go to Page XXXVIII-4.
NO
Consult a turf disease management text for additional information.


FROM PAGE 2: New turf areas
FROM PAGE 3: Established turf areas.
Disease has been identified.
Perform suggested control measures in Section III, for diseases listed in this information package. For control methods for unlisted diseases, see Smiley(1983) or Vargas(1981).
Is turf replacement required as a result of disease damage?
NO
YES
Consult with local USDA Cooperative Extension Service Agent or State university turf specialist to identify turf varieties (adapted for your desired uses) most resistant to the diseases found in your area. Replace diseased turf (and infested soil, if required) with recommended variety or mixture.
Begin a program of turf maintenance and fertilization for disease avoidance (e.g., that described by Vargas, 1981).
Conduct periodic observations of turf for signs, symptoms of nascent infestations of disease fungi.

II. TURFGRASS FUNGUS BIOLOGY AND ECOLOGY:

1. Diseases Described:

A. Anthracnose - Caused by Colletotrichum graminicola. Symptoms include irregularly-shaped patches (from a few inches to several feet across) of yellow-bronze turf. Leaf lesions begin as long reddish spots which may enlarge to encompass the entire leaf blade. Numerous black fungal fruiting bodies (with protruding black spines) can be seen on the leaves as the disease progresses.

B. Brown Patch - Caused by Rhizoctonia solani. Brown Patch generally appears as circular brown patches, from a few inches to several feet across. Infected leaves first appear dark and water-soaked, and eventually dry, wither, and turn dark brown. Brown-to-black fungal fruiting bodies may be found on stolons or under leaf sheaths. The patch may be surrounded, when humidity is high, by a "smoke ring" of fungal mycelium, which dissappears as foliage dries. A musky odor may be perceptable 12-24 hours before the first appearance of the disease.

In the Pacific Southwest, Brown Patch produces a brown ring which surrounds healthy grass.

C. Dollar Spot - Caused by species of Lanzia and Moellerodiscus. Dollar Spot appears as round, bleached-to-straw-colored spots ranging from the size of a quarter to that of a silver dollar, sunken in the turf. Individual spots may coalesce to destroy large areas of turf. Fresh spots may show fluffy gray-white mycelium in the early morning, while grass is wet. Leaf spots appear as bleached-out or light tan lesions over the entire width of the blade, and have red-brown margins (in all hosts except annual bluegrass).

D. Fusarium Blight - Caused by F. roseum and F. tricinctum. Circular spots in infected turf are 6-24" across. The grass in the center of each spot remains healthy, and is surrounded by a band of dead turf (this symptom is called "frog eye"). Especially susceptible varieties (e.g., Pennstar, Fylking) will be killed throughout the spot. Spots begin as dark blue-to-purple, wilted turf, and will turn straw-colored to light tan (dead) if not treated.

E. Gray Snow Mold (also called Typhula Blight) - Caused by species of Typhula. Infected turf develops circular, gray-straw to brown spots (3" to 2' across) as snow melts. Fuzzy, gray-white mycelium may be visible, especially at the margins of the spots, immediately after the snow melts; the color of the mycelium gives the disease its name.

F. Pink Snow Mold (also called Fusarium Patch or Gerlachia Patch) - Caused by Gerlachia nivalis (formerly Fusarium nivale). In the absence of snow, this disease occurs as reddish brown, circular spots from 1-8" across in infected turf; under snow cover, the spots are tan to whitish-gray or red-brown, and expand to 2-3 inches to 1-2 feet in diameter. Immediately after the snow has melted, pink mycelium may be visible at the margins of the spots.

G. Stripe Smut - Caused by Ustilago striiformis, and
H. Flag Smut - Caused by Urocystis agropyri. These diseases cause infected plants to grow upright, giving the turf a clumpy appearance. Infected plants do not tiller profusely, so that weeds fill the bare spots left when individual plants are killed. Leaves of infected plants turn light yellow, then curl and show black parallel stripes which run the length of the blade. Older blades become twisted and shredded from the tip down. The black stripes are surface lesions which produce powdery, black fungus spore masses. Under the microscope, the diseases can be distinguished by the shapes of these spores; stripe smut spores occur singly, while those of flag smut occur in clumps ("spore balls") surrounded by colorless cells.

I. Pythium Blight - Caused by several Pythium species. Early symptoms are circular, red-brown spots, from 1-6 inches across. When dew-covered, infected leaves are water-soaked, dark, and may feel slimy. Leaves shrivel and turn red-brown as they dry. Dew-moistened spots may contain cottony, purple-gray to white mycelium at the margins. Infected plants collapse quickly.

In hot, moist weather, infected areas enlarge rapidly. The disease spreads along drainage patterns, thus it may appear in long streaks.

J. Drechslera Leaf Spot - (Also known as Helminthosporium Leaf Spot.) Caused by Drechslera sativus (formerly Helminthosporium sativum). Early symptoms are small dark purple or black leaf spots. The centers of the spots may become light tan as the spots enlarge. Above 85°F, the entire blade may become involved, appearing dry and straw-colored. Hot, humid conditions promote infection of roots and crowns, resulting in severe thinning of turf.

K. Southern Blight - Caused by Sclerotium rolfsii. Early symptoms are crescent-shaped to circular yellow spots, up to 8 inches across. Turf may become yellow and thin in early summer. The grass in the center of the enlarging spots usually stays green, resulting in the formation of rings of dead grass which may enlarge up to 8" per week during hot humid weather. Spots may enlarge to 3-6 feet. Abundant fluffy mycelium occurs on dying grass at the margins of the spots, and small white or brown fruiting bodies (sclerotia) develop on the mycelium, dead grass, and thatch within the spots.

2. Geographic Distribution:

A. Anthracnose - Occurs throughout the United States (U.S.).

B. Brown Patch - See A., Anthracnose.

C. Dollar Spot - See A., Anthracnose.

D. Fusarium Blight - See A., Anthracnose.

E. Gray Snow Mold - Occurs wherever turf is subject to coverage by heavy, long-lasting snow.

F. Pink Snow Mold - A major problem in the Pacific Northwest, although it may occur anywhere with cool, wet spring or fall weather.

G,H. Smut Diseases - Occur throughout turf-growing areas of the U.S.

I. Pythium Blight - Occurs throughout the U.S., but is usually more serious in the warmer Southern states.

J. Drechslera Leaf Spot - Occurs throughout the U.S.

K. Southern Blight - Occurs in the southern and western portions of the U.S.

3. Habitat:

A. Anthracnose - C. graminicola grows within infected grass tissues, although it can overwinter as a saprophyte in plant debris.

B. Brown Patch - R. solani occurs both within infected tissues of host plants, and in soil, where it survives as a saprophyte.

C. Dollar Spot - These fungi occur only as pathogens in or on infected plants.

D. Fusarium Blight - These fungi can live in the soil as saprophytes, as well as within infected host tissues.

E. Gray Snow Mold - Typhula spp. grow only in infected host tissues.

F. Pink Snow Mold - Gerlachia nivalis will grow in grass debris as a saprophyte, as well as in infected host tissues.

G,H. Smut Diseases - Smut fungi are obligate parasites; they cannot grow except within infected host tissues.

I. Pythium Blight - Pythium spp. survive as saprophytes in soil, as well as in waterlogged areas and in pond debris.

J. Drechslera Leaf Spot - D. sativus grows only in infected host tissue.

K. Southern Blight - S. rolfsii attacks over 500 species of plants, and can survive in soil as a saprophyte.

4. Hosts:

A. Anthracnose - Attacks annual bluegrass, creeping bentgrass, Kentucky bluegrass, fineleaf fescues, and perennial ryegrass.

B. Brown Patch - Attacks all known turfgrasses, as well as many other plant species.

C. Dollar Spot - Attacks annual bluegrass, bahiagrass, bermudagrass, centipedegrass, colonial bentgrass, creeping bentgrass, fine-leaf fescues, Kentucky bluegrass, meadow fescue, perennial ryegrass, St. Augustinegrass, tall fescue, velvet bentgrass, and zoysia.

D. Fusarium Blight - Attacks centipedegrass and Kentucky bluegrass.

E. Gray Snow Mold - Attacks annual bluegrass, colonial bentgrass, creeping bentgrass, fine-leaf fescues, Kentucky bluegrass, perennial ryegrass, tall fescue, and velvet bentgrass.

F. Pink Snow Mold - Attacks annual bluegrass, colonial bentgrass, creeping bentgrass, fine leaf fescues, Kentucky bluegrass, perennial ryegrass, tall fescue, rough bluegrass, and velvet bentgrass.

G,H. Smuts - Attack colonial bentgrass, creeping bentgrass, and Kentucky bluegrass.

I. Pythium Blight - Attacks annual bluegrass, bermudagrass, Kentucky bluegrass, colonial bentgrass, creeping bentgrass, tall fescue, fine leaf fescues, rough bluegrass, perennial ryegrass, annual ryegrass, and redtop.

J. Drechslera Leaf Spot - Attacks annual bluegrass, Kentucky bluegrass, fine leaf fescues, colonial bentgrass, creeping bentgrass, and perennial ryegrass.

K. Southern Blight - Attacks creeping bentgrass, colonial bentgrass, velvet bentgrass, redtop, all fescues, perennial ryegrass, Italian ryegrass, Kentucky bluegrass, rough bluegrass, and annual bluegrass.

5. Disease Cycles:

A. Anthracnose - The fungi survive unfavorable conditions as parasitic mycelium in infected plant debris. When atmospheric humidity is high and grass leaves are wet, the fungi can penetrate roots and leaves. Cushion-shaped fruiting bodies form on killed tissue, and microscopic spores are splashed or blown to new host plants. Infections continue until cold weather resumes.

B. Brown Patch - R. solani can survive unfavorable periods as inert hyphal masses or mycelium in plant debris, or as growing, saprophytic hyphae in soil. Under warm, humid conditions, hyphal masses germinate, and mycelium spreads through thatch or soil, infecting any roots or leaves contacted. Infected tissues collapse, and shrivel rapidly when exposed to sun or wind. Hyphal masses (bulbils) form on/in infected tissues, and are released into the soil as dead tissues decompose.

C. Dollar Spot - These fungi survive unfavorable periods as dormant hyphae in infected plants, and as mycelial masses (stromata) on the surfaces of leaves. When conditions become favorable, the hyphae begin growing out into humid air, infecting any moist leaf they contact. (Roots and rhizomes are not infected). No spores are formed by these fungi in nature, so that fungal distribution to new hosts is by movement of infected grass by people, animals, water, wind, or equipment.

D. Fusarium Blight - Fusarium spp. overwinter as mycelium in infected plants and debris, and as thick-walled, microscopic chlamydospores in thatch or soil. When favorable conditions occur, mycelium grows rapidly and spores germinate. The fungi sporulate freely in moist thatch; spores are carried by wind and water to host plant leaves, roots, or crowns. All parts of the plant can be infected. Sporulation may occur on infected plant leaves.

E. Gray Snow Mold - Typhula spp. oversummer as dark-colored, small sclerotia on infected leaves. When temperatures reach 50-64°F, sclerotia may germinate if humidity is high. Mycelium may be produced directly or may be proceded by basidiospore production. Mycelium may infect grass plants under snow cover. New sclerotia are produced in infected leaves and crowns, and are released into the soil as dead plants decompose.

F. Pink Snow Mold - Gerlachia nivalis survives unfavorable periods as mycelium in infected debris, or as spores in the soil. Under favorable conditions, mycelium infects leaves, spreading rapidly under wet conditions and temperatures between 32° and 61°F. As the turf dries and warms up, the fungus becomes inactive.

G,H. Smuts - Smut fungi overwinter as thick-walled spores in soil, thatch, or infected leaves. Mycelium may survive in nodes and crowns of infected perennial hosts. Spores may remain dormant for up to 3 years. In the spring or fall, overwintering spores germinate, producing microscopic, thin-walled basidiospores. These give rise to new mycelium, which can infect grass coleoptiles or buds. The pathogens become systemic, infecting the entire plant as it grows, producing new overwintering spores throughout the host tissues. These are released into the soil when the plant dies and decomposes.

I. Pythium Blight - Pythium spp. are soil saprophytes, thus are common in soil, thatch, and in the roots of mildly-infected hosts. When conditions become favorable, motile zoospores or mycelium may penetrate host plants, producing new mycelium. The fungi spread from leaf to leaf by mycelial growth. Resting spores (oospores) are produced in or on dead tissues. All spore forms may be transmitted by water, or in infected soil on shoes or equipment.

J. Drechslera Leaf Spot - Drechslera spp. survive unfavorable conditions as spores and dormant mycelium in infected plant tissue and debris. They are saprophytes, and will grow and sporulate when dry debris is moistened. During cool, wet weather (when moisture films can occur on leaf surfaces), spores produce germ tubes which penetrate grass leaves. Lesions occur, and sporulation may occur on larger lesions. Infection may continue until cold weather returns.

K. Southern Blight - S. rolfsii survives as brown sclerotia, which germinate when the temperature is above 23°C, and when moisture is abundant. The

fungus can spread as a saprophyte through the soil, or infect plants of over 500 host species. Stems are attacked above the soil surface. Infected plants collapse, and turn reddish brown. Sclerotia are formed on dead host tissues.

6. Seasonal Abundance:

A. Anthracnose - Occurs during hot, wet weather, but may also be present in spring and fall.

B. Brown Patch - Occurs from late spring through early fall.

C. Dollar Spot - Occurs from late spring through early fall.

D. Fusarium Blight - Occurs throughout the growing season.

E. Gray Snow Mold - Occurs in winter or early spring if snow cover is prolonged.

F. Pink Snow Mold - Occurs whenever cool, wet weather occurs, generally late fall to mid-spring.

G,H. Smuts - Smut symptoms are most visible during spring and summer, when grass grows most rapidly. Plant death is common in hot, dry or windy weather.

I. Pythium Blight - Occurs throughout the calendar year, even under snow.

J. Drechslera Leaf Blight - Can occur anytime except when soil is frozen or above 81°F.

K. Southern Blight - Occurs during warm to hot weather. Cannot survive cold winter conditions (short periods of -4°F).

7. Responses to Environmental Factors:

A. Anthracnose - Requires high humidity and water films on plant surfaces for infection.

B. Brown Patch - Best fungal growth and spread is observed above 82°F. High humidity and prolonged periods of leaf wetting are necessary for infection.

C. Dollar Spot - Requires high humidity for growth.

D. Fusarium Blight - Requires dry soil for sporulation.

E. Gray Snow Mold - Sclerotia require indirect exposure to ultraviolet light (UV) for germination and sporocarp formation. Temperatures between 50°F and 64°F are optimum for germination.

F. Pink Snow Mold - Requires wet conditions and temperatures from 32°F to 61°F for rapid spread.

G,H. Smuts - Infection is favored by low soil moisture and temperatures between 50°F and 68°F.

I. Pythium Blight - Free water is required for infection, and for the spread of zoospores.

J. Drechslera Leaf Spot - Free water on leaf surfaces is required for infection. Sporulation is optimum at temperatures of 59-64°F, but occurs at 37-81°F.

K. Southern Blight - Pathogen spread is favored by high temperatures, waterlogged soil, and high levels of organic matter.

8. Impact of Fungal Diseases:

8.1 Direct Impact: These diseases all can produce aesthetic impacts by destroying or discoloring grassy areas.

8.2 Indirect Impact: Rhizoctonia, Sclerotium, and Pythium spp. attack hundreds of hosts in addition to turfgrass. Any infestation of these fungi can serve as a source of inoculum for infection of other susceptible plantings.

9. Natural Enemies: Although many organisms (competitive fungi, soil bacteria, small arthropods) probably function as natural enemies of these fungi in the field, none is known which can provide effective biological control. Laboratory and field studies have shown, however, that infection of turf by Rhizoctonia solani may be reduced by application of certain nonpathogenic Rhizoctonia (Burpee and Goulty, 1984) or the fungus Trichoderma harzianum (Wells and Bell, 1983).

10. Disease Identification: Solving turf problems requires quick, accurate diagnosis. Unfortunately, many turf diseases are

difficult to identify without access to a well-equipped laboratory. By following the procedures listed below, you will maximize your chances of obtaining the correct diagnosis of any problems you might discover:

1. Observe turf areas regularly for symptoms or signs of problems. In addition, maintain accurate, up to date records of watering and feeding schedules which are followed in your turf maintenance program.

2. If possible symptoms are noted, record the information on a form like the one shown on Page 27. Include all of the information listed on the form, if possible.

3. Using the completed form, attempt to identify the problem using the Turf Disease Key which begins on Page 15. If you cannot identify your problem using this key, consult a photographic turf disease atlas. Two excellent disease atlases are:

   a. Bruneau, A.H., J.E. Watkins, and R.C. Shearman. 1981. Turfgrass disease damage: A common sense approach. Bulletin 104ACB, University of Nebraska, Lincoln, NB 68583-0918. 28 pp. Price $2.00.

   b. Converse, James. 1982. Scott's guide to the identification of turfgrass diseases and insects. O.M. Scott and Sons Co., Department DI, 1411 Scott's Lawn Road, Marysville, OH 43041. 105 pp. Price $7.50.

   c. Smiley, R.W. 1983. Compendium of turfgrass diseases. American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, MN. Price $17.00.

4. Several diseases (e.g., rusts, smuts, mildews) are easily identified by using steps 1-3. However, the assignment of a specific causal agent for many leaf spots, leaf blights, damp-offs, wilts, and root rots is often far more difficult, and may require the facilities of a diagnostic laboratory, such as those maintained by the Plant Pathology departments of State universities. To correctly collect and send a sample to such a laboratory for diagnosis, follow the following procedures:

   a. Collect the sample from an area just beginning to show symptoms. Turf layers about 1 foot

square and 2 inches deep are recommended; half the turf should be from the diseased area (if the disease occurs in patches), and the other half should be from healthy turf. If large samples cannot be collected, collect several samples about 4 inches square and 4 inches deep.

b. Do not soak the samples with water before or after collection, or expose them to heat or sunlight. If the sample is to be mailed, it should be wrapped in several layers of paper or foil (not plastic, which will retain too much moisture, causing the samples to rot). Pack the samples tightly in boxes, along with a copy of the data form discussed above (2), and ship the sample immediately to the nearest diagnostic laboratory by express or priority mail. Be sure to collect and mail such samples early in the week, so that they will not be in a post office or mail room over a weekend. Include your telephone number, so that the diagnostician can contact you regarding your problem.

Remember, turf is a living system, subject to decay as soon as it is removed from its "natural" environment. Accurate identification requires prompt examination of collected samples, so that secondary pathogens (and organisms which may be present in the sample, but not related to the problem) will not overgrow the sample and make diagnosis impossible. The following space is provided for you to fill in the address and phone number of your nearest plant disease diagnosis laboratory:

To find the laboratory nearest you, contact your local USDA Cooperative Extension Service agent or state university plant pathology department.

Key to fungal turf diseases (those marked with an asterisk are included in this IPM Information Package).

Symptoms/Signs	Disease
A. LOOKING AT AFFECTED AREA:	
1. Diseased Area Is Circular	
a. Occurs in winter or early spring:	
i. Red-brown spots 1-8" in diameter (without snow cover). Pink mycelium visible at margins of spots.	Pink Snow Mold *
ii. Tan, white-gray, or red-brown spots from 2-3" to 1-2 feet in diameter. Pink mycelium visible at margins of spots after snow melts.	Pink Snow Mold *
iii. Gray to dark-brown spots from 3" to 2' (usually 6-12") in diameter. Gray-white mycelium can be seen at margins of spots after snow melts.	Gray Snow Mold *
b. Occurs spring, summer, or fall:	
i. Expanding circular patches which may reach up to several feet in diameter.	
aa. Brown patches; may be surrounded by a "smoke ring" of fungal mycelium when humidity is high. Infected leaves become water-soaked and dark, then dry, turning dark brown. In Pacific NW, spot may be a ring with healthy turf in center.	Brown Patch *
bb. Occurs in spring in Bermudagrass. Leaves look dormant, but stolons and roots may be black. Center of spot may be colonized by weeds, thus may appear green from a distance.	Spring Dead Spot
cc. Bronzed-to-bleached spots. Grass in center may be replaced by weeds. Black hyphae are visible under bases of leaf sheaths.	Take-all Patch
dd. Circular spots 6"-24" in diameter. Grass in center healthy, but surrounded by a ring of dead turf (frogeye).	Fusarium Blight *

ee. Large circular zone of stunted turf with inner, outer zones of stimulated growth. Mushrooms may be present in stunted zone.	Fairy Rings
ii. Circular Patches 1-8" In Diameter:	
aa. Grass grows in areas the size of quarters surrounded by similar patches of dead, dying grass; on Toronto creeping bentgrass only.	Drechslera Leaf Blight *
bb. Reddish-brown spots 1-6". Infected leaves are water soaked, dark, and may feel slimy in morning dew.	Pythium Blight *
cc. Bleached or straw-colored spots the size of quarter to the size of a silver dollar. Gray-white mycelium may be visible in spots in the morning. Individual spots may coalesce. Also see leaf symptom 2.b.	Dollar Spot *
dd. Reddish-pink to copper spots, 1-3" diameter in bentgrass.	Copper Spot
2. Diseased Area Is Irregular In Shape:	
a. Yellow to bronze turf. Spots may be a few inches to several feet in size. (Also see leaf symptom 2.a.) Numerous black fruiting bodies can be seen on foliage as disease progresses.	Anthracnose *
b. Yellow-bronze color may change to bronze. Irregular spots begin 1'-2' in diameter, but may enlarge rapidly overnight; on annual bluegrass only.	Helminthosporium Decline
c. Small yellow spots (1/4"-3") may show tufts (dense clusters of yellow shoots arising from single axillary buds or nodes).	Downy Mildew (Yellow Turf)

d. Clumpy turf growth caused by death of individual plants and upright growth of others. Also see leaf symptom B.1.e.	Smuts
e. Irregular patches up to a few feet across. Slimy gray, white, blue, or yellowish masses, or large numbers of smaller bodies may cover individual leaves.	Slime Molds

B. LOOKING CLOSELY AT LEAVES:

1. Fungus Growth Is Visible On Blade:	
a. White, powdery patches.	Powdery Mildew
b. Red mycelial growth that swells and becomes gelatinous when wet.	Red Thread
c. Elongated reddish leaf pustules. Yellow to dark brown spores protrude through breaks in the epidermis	Rusts
d. White, gray, yellow, or bluish slimy, irregular shaped masses cover leaf surface.	Slime Molds
e. Blades light yellow, curled. Black stripes lengthwise along leaf, bearing black spores.	Smuts *
f. Gray-white mycelium on leaves at margins of diseased area.	Gray Snow Mold *
g. Pink mycelium visible at advancing edge of diseased area.	Pink Snow Mold *
2. Fungus Is Not Visible, But Leaf Spotting Occurs:	
a. Elongate red to brown spots on leaves; may enlarge to cover entire blade.	Anthracnose *
b. Bleached or tan lesions cover entire width of blade with reddish-brown bands at ends (except in annual bluegrass).	Dollar Spot *

c. Leaf spots with tan centers and reddish-brown margins.	Fade-out
d. Tiny brown spots which enlarge, become elongate. Mature spots have gray centers with brown margins surrounded by chlorotic (yellowed) tissue.	Gray Leaf Spot
e. Irregular brown to purple-black lesions on blades of annual blue grass. Black fruiting bodies may be visible in newly killed tissue.	Helminthosporium Decline
f. Small purple to black spots. Older spots may have tan centers.	Drechslera Leaf Spot *
g. Tiny purple to black spots which may enlarge, eventually covering entire width of blade: on fine-leafed fescues.	Drechslera Blight
h. Dark transverse strands resembling dark threads across leaf: on broad-leafed fescues.	Drechslera Net Blotch
i. Small brown spots on blades which enlarge, developing white centers: on ryegrass spp.	Drechslera Brown Blight
j. Dark brown streaks on leaf blade: on ryegrass spp.	Drechslera Brown Blight
k. Small olive-green spots on leaves may become large, green-brown to black blotches: on Bermudagrass.	Drechslera Leafblotch
l. Black to purple spots on leaf blades: on Kentucky bluegrass.	Drechslera Melting-out
m. Small, dark red spots on leaf blade. These enlarge, becoming straw colored with red-brown borders: on red top and bentgrass.	Drechslera Red Leaf Spot
n. Leafspots small, red: enlarge to cover entire width of blade.	Copper Spot

III. TURFGRASS FUNGUS DISEASE MANAGEMENT

1. Population Monitoring Techniques:

Population monitoring techniques have not been developed specifically for most turf fungus diseases. The most effective technique available is frequent (i.e., weekly) observation of your turf for symptoms or signs of disease, especially during those periods when outbreaks are most likely to occur:

A. Anthracnose - Hot, humid weather, and/or when water is present on leaves for long periods.

B. Brown Patch - See A., Anthracnose.

C. Dollar Spot - Hot, humid weather with dry soil.

D. Fusarium Blight - See C., Dollar Spot.

E. Gray Snow Mold - Cool, wet conditions followed by snow.

F. Pink Snow Mold - Prolonged cool, wet weather.

G,H. Smuts - Hot, dry weather.

I. Pythium Blight - Hot, humid weather, or periods of soil saturation under heavy snow cover.

J. Drechslera Leaf Spot - Wet weather (warm or cool).

K. Southern Blight - Hot, wet weather.

A sample turf disease report form is shown on Page 27 of this package. Regular reporting of turf disease outbreaks on such forms will permit identification of especially susceptible areas, and will aid in planning each season's disease control effort.

Techniques for predicting disease outbreaks on the basis of weather conditions are being developed for the following diseases:

A. Anthracnose - Danneberger, et al.(1984) have developed a technique using average daily temperatures and foliar wetness durations to predict outbreaks. This method requires complicated calculations,

which are difficult to perform by hand. A computerized device will soon (expected in 1985) be available from Reuter-Stokes Co., Cleveland, OH, which will measure necessary data and perform the required calculations. The device will be sold as the "Turfgrass Disease Predictor", at a price of about
$2000.

B. Brown Patch - J.M. Vargas, Jr. (personal communication) is developing a predictive model for this disease, which will be incorporated into the Reuter-Stokes Turfgrass Disease Predictor. The model is not currently complete.

C. Pythium Blight - P.O. Larson, at Ohio State University, Columbus, is developing a weather-based model for prediction of Pythium outbreaks (J.M. Vargas, Jr., personal communication); the model is not yet available.

2. Threshold/ Action Population Levels:

The pest population (measured as numbers of diseased patches, or percentage of infected plants per unit area) which will be viewed as causing unacceptable turf damage depends on the turf use. High-value areas, such as golf course fairways and greens, are the least tolerant of any fungus damage. Any such damage is unsightly, may affect playability, and lead to visitor nonacceptance. Low-value areas, such as general building lawns, parking areas, and campgrounds can accept more visible damage. Careful maintenance of turf damage records by park personnel may give an indication of how much disease can be tolerated in a given turf site.

3. Management Alternatives - Nonchemical:

A. Anthracnose

1. Cultural Controls

a. Watering - Watering should not be done in the late afternoon or evening. Water deeply but infrequently during periods of drought or high temperatures.

b. Fertilization - Use no more than 1/2 lb nitrogen per 1,000 ft^2 per month during hot weather. Maintain normal levels of phosphorous and potassium.

2. Resistance - Contact your nearest State university Turf specialist for information on resistant turfgrasses for your area.

B. Brown Patch

1. Cultural Control

a. Watering - "Dew" should be removed from turf as early as possible in the morning; this can be done by dragging a hose or bamboo pole over the affected area, or by spraying the turf with water. The "dew" is actually largely made up of nutrient-rich leaf exudates which can promote fungus growth.

b. Fertilization - See Anthracnose, section A.1.b.

2. Resistance - Unknown.

C. Dollar Spot

1. Cultural Controls

a. Watering - See Brown Patch, B.1.a. Also keep soil near field capacity.

b. Fertilization - See Anthracnose, A.1.b.

2. Resistance - Unknown; however, some grass varieties may be less susceptible than others. Contact your nearest State university turf specialist to determine the best varieties for your area.

D. Fusarium Blight

1. Cultural Controls

a. Watering - Water lightly and frequently to keep the top inch to 1/2 inch of soil or thatch moist. In addition, turf should be sprayed for about 5 minutes during the warmest part of the day.

b. Fertilization - Fertilize early in the fall, again after top growth has stopped, and use only frequent, light applications through the summer. Maintain a thatch and soil pH of 6-7.

2. Resistance - Contact your nearest State university turf specialist for information on resistant varieties for your area.

E. Gray Snow Mold

1. Cultural Controls

a. Fertilization - Avoid heavy feeding within six weeks of expected dormancy. Fertilizer should be applied before this time, or after dormancy. Slow-release forms of nitrogen are recommended. Feed affected turf lightly in the spring.

b. Mechanical Treatment - Mow grass to its normal height after dormancy. Avoid excess thatch accumulation. Prevent compaction. Prevent large snowdrifts by proper use of snow fences. Promote rapid heating and drying of affected patches in early spring by raking.

2. Resistance - Resistant varieties may be available; contact your nearest State university turf specialist for information.

F. Pink Snow Mold - See Gray Snow Mold, section E. Also maintain balanced soil fertility and a low soil pH.

G,H. Smuts

1. Cultural Controls

a. Watering - Infected turf should not be allowed to dry out, or grass will die.

b. Fertilization - See Anthracnose, A.1.b.

2. Resistance - Resistant varieties may be available, but the fungi are able to overcome the available type of resistance. A mixture of resistant varieties may be more effective than a single variety. Contact your nearest State university turf specialist for information on the best varieties for your area.

I. Pythium Blight

1. Cultural Controls

a. Watering - Light watering after sunrise and a 5-minute spray at midday are recommended where soil drainage is poor. (Good soil drainage will help prevent Pythium blight).

b. Fertilization - See Anthracnose, A.1.b.

2. Resistance - Most improved bermudagrass cultivars are resistant to Pythium blight. Resistance is currently unknown in other grasses.

J. Drechslera Leaf Spot

1. Cultural Controls

a. Watering - Keep turf damp when the fungus is active.

b. Fertilization - Little or no nitrogen should be applied during warm weather. Maintain adequate levels of phosphorous and potassium.

2. Resistance - Currently unknown.

K. Southern Blight

1. Cultural Controls - Aerification of soil, removal of thatch accumulations, and maintenance of a soil pH above 8.0 may reduce fungal activity. Normal fertilization is recommended.

2. Resistance - Currently unknown.

4. Management Alternatives - Chemical:

A variety of fungicides are available for the control of the listed diseases. Consult with your local turf specialists and your NPS IPM Coordinator to determine which (if any) fungicide is best for your problem.

Summary of Management Recommendations:

Control of the majority of fungal turf diseases involves maintenance of proper irrigation and fertilization, the use of resistant grass varieties, and regular inspection for disease symptoms. For low to medium value areas, cultural control techniques should be sufficient to provide useful disease management. Treatment of high-value turf with recommended fungicides may be necessary . Consult with your local U.S. Department of Agriculture (USDA) Cooperative Extension Service agent or nearest State University turf specialist for information on the optimum turf management program for your area.

Prompt, accurate disgnosis of turf problems can prevent small disease outbreaks from becoming large, costly ones. Keeping a photographic atlas of turf diseases will help your personnel in identifying disease problems. Good record keeping (of irrigation, fertilization, and pesticide use) and frequent observation will allow the most rapid identification and treatment of turf diseases.

IV. BIBLIOGRAPHY

Copies of the following articles may be obtained by contacting the IPM Coordinator, WASO.

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Vargas, J.M., Jr. 1981. Management of turfgrass diseases. Burgess Publishing Co., Minneapolis, MN. 204 pp.

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Wells, H.D., and D.K. Bell. 1983. Variable antagonism in vitro between isolates of Trichoderma harzianum and Rhizoctonia solani AG4. Phytopathol. 73:507 (Abstr.).

V. PERSONAL COMMUNICATION

J. M. Vargas, Jr.
Dept. of Botany and Plant Pathology
Michigan State University
East Lansing, MI.

VI. SAMPLE TURF DISEASE REPORT FORM

Be certain to include all of the information required below, when reporting turf symptoms.

1. Species and cultivar(s) of turfgrass affected:

2. Age of grass stand:

3. Overall symptoms: (Is the disease uniform throughout the area, or is it in low or wet areas only? Do the symptoms occur in circular or irregular patches? How large are they? What color are they? Do patterns suggest involvement of equipment? Are holes apparent in affected turf? Can plants be pulled out easily, or are they firmly rooted?).

4. Specific symptoms and signs on leaves of affected plants (spots, yellowing, watersoaking, banding, shape and color of lesions, presence of fungal mycelium and/or fruiting bodies, color of fungal signs, etc.). Describe as fully as possible; use of a 10X or 20X magnifier will aid in identification of symptoms.

5. Soil type (clay, sandy loam, etc.) and depth (inches):

6. Soil drainage (good, poor, etc.):

7. Air movement over affected area (free; blocked by buildings, etc.):

8. Irrigation (dates, how applied) schedule for past month:

9. Fertilization schedule (types, quantities, dates of application):

10. Pesticide schedule (types, use rates, dates of application):

11. Cultivation schedule (methods, dates):

CONTINUED

12. Weather conditions (temperature, humidity, rainfall, etc.):

    a. Just before symptoms developed:

    b. At the time of symptom development:

13. Date symptoms were first observed:_____

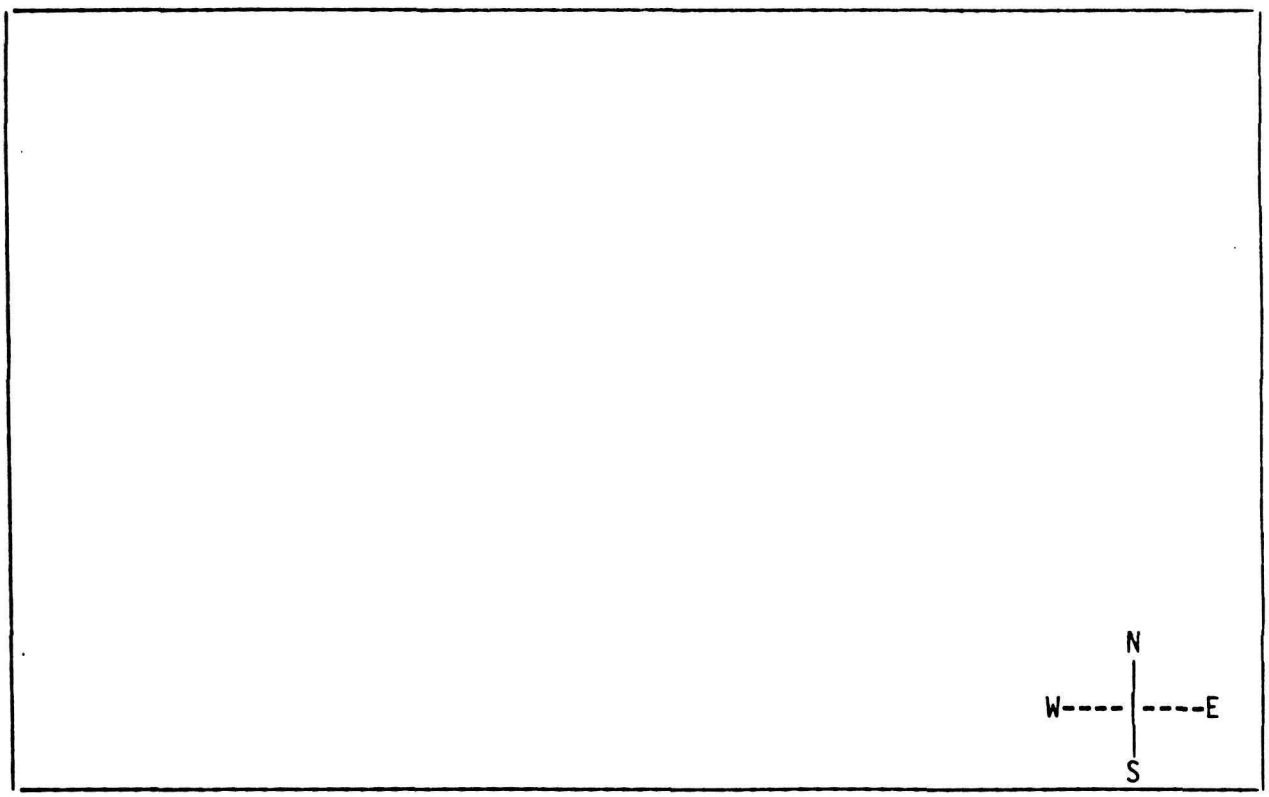
14. Date samples were collected:_____ Sent to diagnostic laboratory:_____

15. Diagnosis:

16. Suggested treatment:

17. Details of treatments used (type, method of application, date and by whom applied):

18. Use this block to sketch the affected site and surrounding area.



NATIONAL PARK SERVICE
IPM Information Package

TURF INSECTS

Final Report

30 September 1984

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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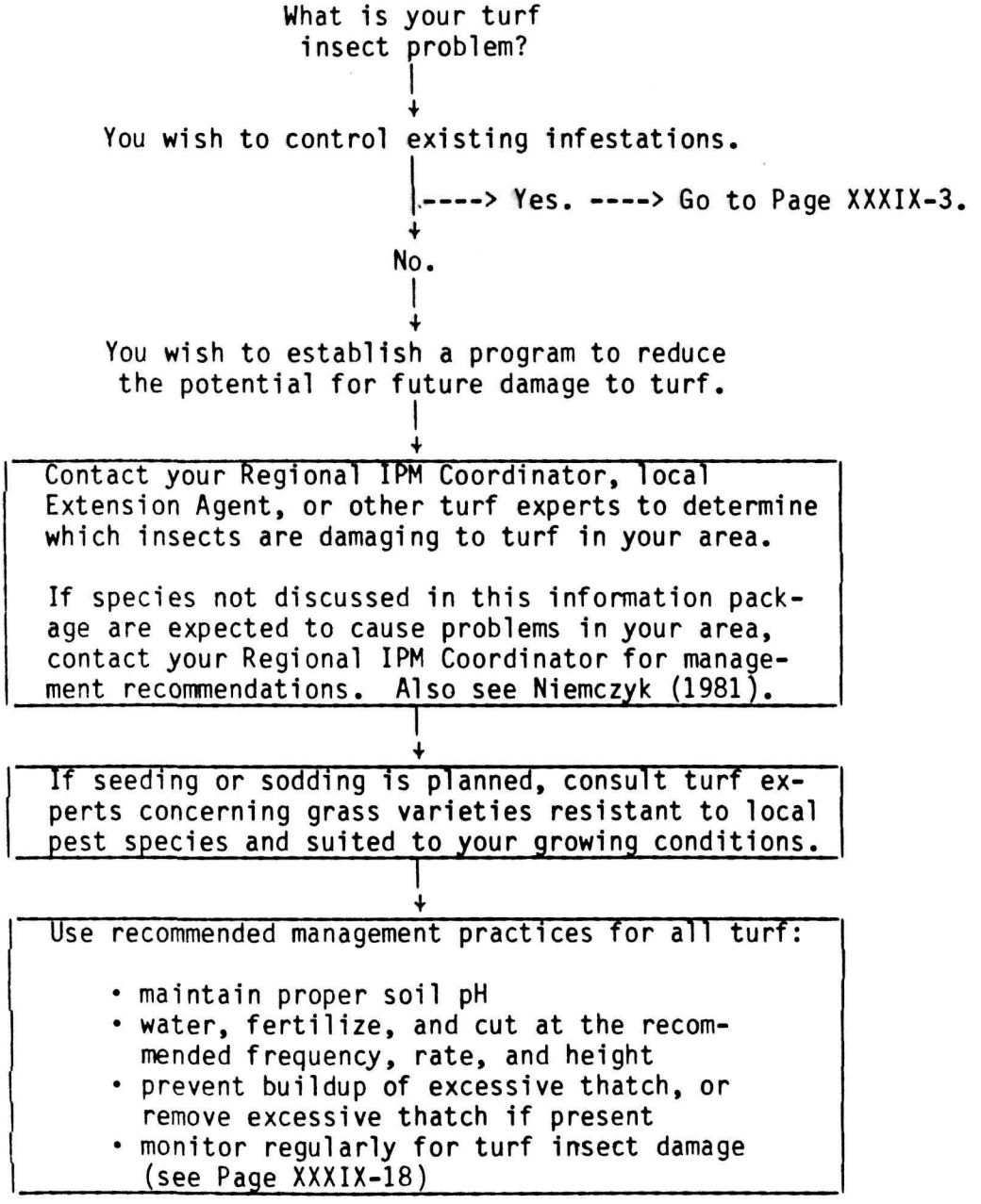
I. TURF INSECTS IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.



You wish to control existing infestations.

↓

Identify the species causing damage, using information in this Information Package, and/or sources noted on Page XXXIX-5.

↓

Soil-dwelling, root-feeding insects.

↓ Yes

↓

Monitor using cup-cutter or spade techniques (white grubs), or soap flush technique (mole cricket). See Pages XXXIX-18-19.

↓

Damage is caused by, and monitoring indicates that population levels have exceeded the threshold for (see Section III.2 for information on establishing thresholds for these insects):

↓

Japanese Beetle

Yes → Apply milky spore disease to infested areas. → Consider applying a registered and approved insecticide if needed.

↓ No.

Black Turfgrass Ataenius

Yes → Consider applying a registered and approved insecticide to kill larvae. → Alternatively, apply a registered and approved insecticide next spring when adults emerge (see Page XXXIX-25).

↓ No.

May or June beetles

Yes → Consider applying a registered and approved insecticide in July or August.

↓ No.

Mole Crickets

Yes → Consider applying a registered and approved insecticide in July, when nymphs are small.

↓ No.

Other species → See Page XXXIX-5 for sources of information on insects not listed in this Information Package.

No → Thatch-dwelling, stem- and leaf-feeding insects. → Go to Page XXXIX-4.

Continued from Page XXXIX-3.

Thatch-dwelling, stem- and leaf-feeding insects.

Monitor with soap flush technique (sod webworm and armyworm), or water float technique (chinch bugs). See Pages XXXIX-18-19.

Damage is caused by, and monitoring indicates that population levels have exceeded the threshold for (see Section III.2 for information on establishing thresholds for these insects):

Sod Webworms

----->Yes.---> For control of 1st and 2nd instar larvae, apply *Bacillus thuringiensis*. For larger larvae, consider application of a registered insecticide.

No.

Armyworms

----->Yes.---> Apply registered insecticide. Monitor throughout summer for larvae, and repeat treatment when threshold is again exceeded.

No.

Chinch Bugs

----->Yes.---> Monitor in spring for adults migrating to turf from overwintering sites, and consider treatment with a registered insecticide to prevent damage later in summer. Monitor throughout summer and retreat when thresholds are again reached. Avoid treatment when big-eyed bugs or *Beauveria* are present.

No.

Other Species

See Page XXXIX-5 for sources of information concerning insects not discussed in this Information Package.

II. TURF INSECTS BIOLOGY AND ECOLOGY

While many species of insects damage turfgrass in the United States, this package describes in detail the life histories and management of several of those which have been found to be frequent problems within the National Park System. Photographs of and further information concerning these and other turf pests can be found in publications such as Niemczyk (1981), Daley (1975), Shetlar (1982), or Converse (1982).

1. Species Described:

A. White Grubs - These are the larvae of many species of beetles, most of which belong to the family Scarabaeidae. Although the adults differ from one another in appearance and life cycles, the grubs of all species are similar in appearance. Fully grown larvae are 1/2 - 3/4" long, white to grayish, with brown heads and six legs. They generally assume a C-shaped position while in the soil. Grubs can be identified to species on the basis of the pattern of hairs (raster) found on the underside of the last abdominal segment. The raster is easily seen using a 10x magnifier.

Although numerous species of grubs cause turf damage, three are described in detail in this report.

1. Japanese Beetle - Popillia japonica Newman. The adult male beetle is 5/16 - 3/8" long; the female is slightly larger. The beetle is roughly oval in outline (from above). The head and prothorax are greenish bronze, and the wing covers are brownish bronze with green along the sides and center. Twelve white tufts of hair are present along the sides of the abdomen and at the tips of the wing cover. Antennae are platelike. The legs are long, with heavy claws. Eggs are round, becoming oval, measuring less than 1/16" across. Larvae molt twice; a third instar grub can be up to 1" long. The head is brown, with large, brown-black mandibles. The raster includes two converging rows of 6 hairs each, originating from a transverse anal slit. Pupae are tan and spindleshaped; appendages are held away from the body.

2. Black Turfgrass Ataenius - Ataenius spretulus Haldeman. Adult beetles are red-brown, darkening to black with aging. They are roughly oval in shape, and may be up to 3/8" long. Eggs are round, very small, and are laid in clusters of 8-12 in thatch. Larvae are no longer than the adults, but resemble other grubs in color,

shape, and resting position in soil. Larvae can be identified by the presence of two padlike structures near the anal slit, and the scattered raster pattern (use a 10x lens to observe this).

3. May or June Beetle - Phyllophaga spp. Adults are 3/4 - 1 3/8" long, stout, shiny red-brown to blackish-brown. Antennae have 3 platelike segments forming a club-like structure at a right angle to the other segments. The head, prothorax, and wingcovers usually have no distinguishing markings or grooves. Larvae are white with brown heads, have large jaws, and have an elongated raster featuring two parallel lines (oriented front to rear on the segment) of hairs.

B. Mole Crickets - Members of the family Gryllotalpidae. Adults are 1 1/2 - 2" long, and may be greyish-brown to brown in color, with enlarged heads, beadlike eyes, short antennae, and robust, spadelike front legs. Forewings are usually 1/2 the body length, while the hindwings may extend beyond the tip of the abdomen when folded. Mole cricket nymphs resemble adults, but are smaller and wingless. Eggs are deposited in clusters in the soil.

C. Sod Webworms - Crambus spp. Webworm adults are small, beige to gray-white moths (Lepidoptera) with a wingspread of 3/4". The head has a snoutlike projection at the front. Wings are folded close to the body when a moth is at rest. Larvae (the turf-damaging stage) are caterpillars which may be greenish, brown, beige, white, yellow, or gray, depending on the species. They are 3/4" long when mature, and usually have dark, circular spots scattered over the body. They spin threads of silk as they move, webbing leaves and soil particles together, and often forming silk tubes in which they live.

D. Armyworms - The larvae of two noctuid moths.

1. True Armyworm - Pseudaletia unipuncta (Haworth). Adults are buff to sand-colored, with a wingspread of about 1 1/2". Each forewing has a central white dot, and each hindwing has a dark margin. Fully-grown larvae, the turf-damaging stage, are nearly hairless, smooth, green to brown, and have one dark stripe along each side, and a broad dark stripe along the upper surface; the top stripe may have a light, thin,

broken line along its center. These stripes run the entire length of the body. The head of the larva is light brown with a green tinge and dark brown mottling.

2. Fall Armyworm - Spodoptera frigiperda (Smith). Adults resemble those of true armyworms in form, but have dark gray forewings mottled with light and dark spots, and grayish-white hindwings. Larvae are gray to yellow-green, and have stripes similar to those of P. unipuncta. Each larva has a prominent, white, inverted Y-shaped spot on the front of the head. Long hairs arise from black tubercles along the body.

E. Chinch Bugs - Blissus spp. These are true bugs (Hemiptera). Two species of chinch bugs are of primary concern in turf; the southern chinch bug, a pest of warm-adapted turfgrasses, and the hairy chinch bug, a pest of cool-adapted turfgrasses. Adults are black, about 1/5" long, with white wings folded over the back. Each wing is marked with a dark triangle on the outer margin. Some individuals have short wings (about 1/2 the length of the body), while the wings of others extend to the tip of the abdomen. The legs and the bases of the antennae are red. Juveniles (nymphs) resemble adults, but are wingless; the youngest nymphs are bright red with a single white band across the body, but darken as they mature. Eggs are elongate, and about 1/15" long.

2. Geographic Distribution:

A. White Grubs -

1. Japanese Beetle - This pest is an Asian native, which was first reported in the U.S. at Riverton, New Jersey, in 1916. It is common in all states east of the Mississippi River, except Florida, Mississippi, and Wisconsin. It has also been found in Missouri, Minnesota, and California.

2. Black Turfgrass Ataenius - This beetle has been found throughout the United States, except in the dry Southwest.

3. May or June Beetles - These beetles occur throughout North America.

B. Mole Crickets - Mole crickets occur in the South Atlantic and Gulf Coast regions, from Virginia to Texas.

C. Sod Webworms - These moths occur throughout the United States and Canada.

D. Armyworms -

1. True Armyworm - Occurs throughout the United States east of the Rocky Mountains, as well as in New Mexico, Arizona, and California.

2. Fall Armyworm - May occur throughout the United States in the warmer months, but is found all year in the southern states.

E. Chinch Bugs - Occur throughout the United States. The southern chinch bug is a pest in the Gulf states, Georgia, South Carolina, and North Carolina. The hairy chinch bug is a pest of the more northern eastern states.

3. Habitat:

A. White Grubs - These insects inhabit the soil or sub-surface layer of turf beneath the thatch.

1. Japanese Beetle - Open woods, meadows, lawns, grasslands, and cultivated fields.

2. Black Turfgrass Ataenius - See A.1. Problems have only been noted on golf courses.

3. May or June Beetles - See A.1.

B. Mole Crickets - These insects can become pests in the sub-surface layer of turf in moist, sandy soils.

C. Sod Webworms - The larvae live in the thatch layer in grasslands, lawns, golf courses, and cultivated fields.

D. Armyworms - The armyworms are thatch-dwelling insects in grasslands, lawns, golf courses, and cultivated fields.

E. Chinch Bugs - The species of chinch bugs infest thatch in grasslands, turf, and cultivated fields.

4. Hosts:

A. White Grubs - The larvae of these insects feed on the roots of grasses, and occassionally other plants.

1. Japanese Beetle - Attacks more than 275 species of woody and herbaceous plants, including many

trees, ornamental shrubs and vines, fruits, flowers, vegetables, and weeds. Adults feed on foliage and fruit, while larvae feed on roots, especially those of grasses, vegetables, and nursery plants.

2. Black Turfgrass Ataenius - The primary hosts are annual bluegrass, bent grass, and Kentucky bluegrass.

3. May or June Beetles - Adults eat the foliage of deciduous or coniferous trees. Larvae feed on the roots of bluegrass, as well as those of timothy, corn, soybeans, and other crops, and the tubers of potatoes.

B. Mole Crickets - Nymphs and adults feed on various grasses; Bermuda grass and bahia grass appear to be the major hosts, at least in Florida (Reinert 1982a). Mole crickets also feed on garden vegetables, tobacco, peanuts, and strawberries. Underground stems, roots, tubers, and fruits touching the ground may be consumed.

C. Sod Webworms - Attack grass, and occasionally cultivated crops grown in soil previously under sod.

D. Armyworms -

1. True Armyworm - Attacks grasses, small grains, corn, alfalfa, sugarbeets, clover, and tobacco.

2. Fall Armyworm - Attacks grasses, corn, cotton, alfalfa, clover, peanuts, tobacco, and many garden plants.

E. Chinch Bugs - Attack grasses; bluegrasses, zoysia grass, and especially St. Augustine grass (southern chinch bug, Reinert 1982a), and Kentucky bluegrass, fine fescues, and bent grasses (hairy chinch bug, Reinert 1982b). They also are pests of small grains, corn, and sorghum.

5. Life Cycles:

A. White Grubs -

1. Japanese Beetle - One generation is produced each year. Adults emerge from the ground from late spring to mid-fall. The beetles are strong fliers, and are attracted to silhouettes against the sky on clear days. Males and females may gather in large swarms around trees or sources

of fruity or floral odors, and feed on fruit and leaves and mate for about a week. Adults live 3-4 weeks after emergence. After mating, females fly to moist, grassy areas with sunny exposures and loamy soils of pH 5.3 or less. Each female burrows 2-5" into the soil, and begins laying single eggs in hollowed-out chambers. A single female may lay 50 eggs. Egg laying occurs from early midsummer to mid-fall. Eggs hatch in about 2 weeks; hatchlings tunnel to just below the soil surface, and begin feeding on grass roots. By late fall, most larvae are fully grown; they tunnel 5-8" below the soil surface to hibernate. Activity resumes in the following early spring; the larvae tunnel to within 2" of the soil surface to feed. Between mid-spring and midsummer, larvae hollow out chambers in the soil and pupate. After 2-3 weeks the adults emerge.

2. Black Turfgrass Ataenius - There are 1-2 generations per year, depending on climate. There are two generations each year in Ohio, but only one in states farther north (Niemczyk 1981). Adults overwinter 1-2" below the surface in well-drained soils, or under leaves and other debris near wooded areas. They emerge in April, mate, and females burrow into soil under turf. During May and June, clusters of 8-12 eggs are laid in thatch or the top 1/2" of soil. Larvae are present from late May to mid-July in thatch and soil, feeding on bent grass, annual bluegrass, or Kentucky bluegrass. In late June to July, mature larvae burrow 1-3" into the soil, pupate, and emerge as adults in July and early August. First generation adults lay eggs in July. The second generation larvae complete development and pupate in late August or September. The new adults emerge and seek final overwintering sites during September and October.

3. May or June Beetles - These beetles have a 3-year life cycle. Eggs are deposited 1-8" deep in the soil in late spring. The eggs hatch in about 3 weeks, and young larvae begin feeding on roots and decaying vegetation. In the fall, they migrate down into the soil, where they overwinter. They resume root feeding in the following spring. After a summer of damaging feeding, they hibernate deep in the soil over their second winter, and then rise to near the surface to feed again until about June. Pupa-

tion then occurs in a hollowed cavity in the soil. The new adults emerging from these pupae (in about 3 weeks) remain in the hollow cavities through the following winter, and only emerge the following May or June, when feeding, mating, and egg-laying occur.

These insects require three years to complete their development from egg to adult. However, adults are present every year because there are three different broods which produce adults in different years. Brood A (with adults to be seen in 1986, 1989, 1992, and so on) produces the greatest damage. Next in importance is Brood C (adults in 1985, 1988, 1991, etc.). Brood B (adults in 1987, 1990, 1993, etc.) is of least importance, since it consists of the fewest individuals (Davidson and Lyon 1979).

B. Mole Crickets - Nymphs and adults migrate deep into the soil during cool weather, and pass the winter in the soil. In spring and early summer, eggs are laid in cells which the females construct in the soil. About 35 eggs are laid in each cell. These hatch in 10-40 days, depending on ambient temperatures. Nymphs grow rapidly, most becoming adults before mid-winter.

C. Sod Webworms - These pests generally overwinter as larvae, in cases of silk covered with soil at or below ground level. They feed in the spring, passing through 7-20 instars before pupating in soil-covered silk cases. Adults appear and mate in the summer. Females deposit eggs, singly or a few at a time, often while flying over grassy areas. Eggs hatch in about one week. Two or three generations may be produced each year in warmer areas.

D. Armyworms -

1. True Armyworm - This pest passes the winter as partially-grown larvae in the soil or under debris in grassy areas. No resting stage occurs; activity and growth are continuous except during very cold weather. Larvae which successfully overwinter feed during the following spring. When fully grown, they stop feeding for four days, then pupate for 15-20 days. Adults emerge in May and June. Mating takes place at night, especially during the 5th hour after sunset (Pfadt 1978); multiple matings usually occur. Females feed for 7-10 days on honeydew, nectar,

or decaying fruit before laying eggs. Eggs are laid at night in clusters of 25-134 on grass or grain leaves. A single female may live as an adult for 17 days and produce up to 2000 eggs. Eggs hatch in 6-10 days. Young caterpillars begin feeding on leaves, especially at night or during cloudy weather. They usually hide in the thatch during daylight hours. Six larval instars are passed in 3-4 weeks; the last instar consumes 80% of the foliage eaten during the insect's lifespan. Full-grown larvae pupate in flimsy silk cocoons under litter or in earth cells 2-3" below the soil surface. Following pupation, in August or September, the emerging adults mate and lay eggs. Larvae develop partially before winter. The number of generations produced each year increases as latitude decreases; 3-4 are produced in the central states, while 5 or more generations are produced in the South.

2. Fall Armyworm - The life cycle of this moth is similar to that of the true armyworm; see D.1. Although primarily a pest in the South, fall armyworm adults migrate northward each year, and have reached pest status as far north as Minneapolis (Niemczyk 1981). Successful overwintering occurs only in the South.

E. Chinch Bugs - These insects overwinter as adults, hiding in tufts of bunching grasses, under litter or leaves at woodland borders, under hedges, in fence rows, or in sorghum stubble. Winter inactivity may be broken by abnormally warm weather. Generally, migration from winter sites begins after 1 or 2 sunny days with temperatures of 70°F or more. Adult bugs fly to turf (or small grains, corn, or sorghum). After reaching their destinations, they mate, and females begin laying eggs on leaf sheaths, on roots, or on the soil near host plants. Fifteen to 20 eggs per day are deposited in 2-3 weeks. Eggs hatch in 1-2 weeks, and nymphs begin sucking juices from host plants. The bugs pass through 5 instars in 30-90 days, before reaching adulthood. The eggs produced by this generation of females become the next generation of adults in late summer and early fall. From August to October, these adults gradually migrate to their winter sites. In the Southwest, a third generation may be produced before hibernation.

6. Seasonal Abundance:

A. White Grubs -

1. Japanese Beetle - Adults are most common from late spring to early fall, with a peak (in New York and New Jersey) around late July to early August. Larvae are not usually seen, but symptoms of feeding are most severe in August and September.

2. Black Turfgrass Ataenius - Adults appear in late March and April, and again (the next generation) in mid-July to August. Symptoms of larval feeding are visible from mid-June through September.

3. May or June Beetles - Adults emerge in May and June. Larval feeding damage may occur throughout the growing season.

B. Mole Crickets - Adults and nymphs may appear from early spring to late fall, but will not be seen during cold weather.

C. Sod Webworms - In the northern portion of their range, larvae will appear in the early to late spring, and again (the next generation) in late summer to early fall. Adults emerge during the summer. In the South, all forms may exist simultaneously.

D. Armyworms -

1. True Armyworm - Caterpillars emerge in early spring, and again in the summer (and fall, if a third generation is produced). Adults appear in May and again in August. In the Gulf Coast states, all stages may be present at any time.

2. Fall Armyworm - See D.1.

E. Chinch Bugs - Adults appear in early to mid-spring, and again in August through October. Nymphs may be seen throughout early to mid-summer.

7. Responses to Environmental Factors:

A. White Grubs -

1. Japanese Beetle - Adults are day flyers, and are attracted to silhouettes against a sunny sky, and to geraniol (a fragrant compound produced by roses and certain other flowers). Females prefer to lay eggs in acidic soil with a pH of 5.3 or less. Dry soil conditions in late summer result in high egg and grub mortality.

2. Black Turfgrass Ataenius - Adults are night fliers, and are attracted to ultraviolet light.

3. May or June Beetles - Adults are attracted to light.

B. Mole Crickets - Nymphs and adults are most active at night. Adults are attracted to light.

C. Sod Webworm - Caterpillars become active when soil temperatures rise above 50°C. Larvae feed during the night and hide in silk tunnels during the day.

D. Armyworms -

1. True Armyworm - Outbreaks are most common after cold, wet spring weather. In seasons of unusual abundance, larvae may crawl in large groups from one food source to another (hence their common name). Armyworms cannot survive exposure to temperatures above 88°F.

2. Fall Armyworm - Overwintering cannot occur in the northern states. Larvae, when unusually numerous, will migrate in search of food.

E. Chinch Bugs - Movement from overwintering sites does not take place before ambient temperatures reach 70°F. Heavy rains may drown young nymphs, and may cover eggs with mud, preventing hatching.

8. Impact of Turf Insects:

8.1 Direct Impact:

A. White Grubs -

1. Japanese Beetles - Damage consists of irregularly-shaped patches of dead turf. The larvae cut the grass roots, loosening the sod, which can be rolled up like a carpet. Grass usually does not recover from severe injury. Attack by even small numbers of grubs causes yellowing and slowing of grass growth. Adult beetles skeletonize leaves, and gouge and pit fruits of many trees, shrubs, and herbaceous plants.

2. Black Turfgrass Ataenius - Larvae may cause dead patches of grass, or may cause symptoms similar to those of heat stress (e.g., weak growth and wilt). Grass under stress due to

heat, drought, or heavy traffic will develop the most obvious symptoms of black turfgrass ataenius injury. Damage is most evident in July and August, especially if the weather is warm. Grass usually does not recover from severe injury.

3. May or June Beetles - Larval damage to turf is similar to that caused by Japanese Beetle grubs (see III.8.A).

B. Mole Crickets - Immatures and adults burrow in loose soil, feed on grass roots, and cause turf to dry out. Damage is usually localized in irregular areas, and can be severe in newly-planted turf.

C. Sod Webworms - Larvae eat grass blades, and often sever entire plants at the crown. This damage appears as irregular areas of dead grass. Grass usually recovers if watered and fertilized.

D. Armyworms -

1. True Armyworm - Larvae skeletonize leaves, and may sever entire plants at the crown. They may cause considerable damage when numerous, but the grass usually recovers if watered and fertilized.

2. Fall Armyworm - See D.1.

E. Chinch Bugs - These bugs damage grass plants by inserting hollow, needle-like beaks into the stems, sucking the plant juices, and injecting chemicals into the plants which clog the vascular system. Damage appears as patches of dead or gradually yellowing grass, especially where heat is radiated into the grass from sidewalks or roadways. Damaged grass does not recover.

8.2 Indirect Impact:

A. White Grubs -

1. Japanese Beetle - Birds and mammals such as mice, shrews, moles, and skunks create holes by digging in infested turf in search of grubs.

2. Black Turfgrass Ataenius - See A.1.

3. May or June Beetles - See A.1.

B. Mole Crickets - Adults may create nuisances during

spring mating flights, when large numbers may be attracted to lights at night.

C. Sod Webworms - See A.1.

D. Armyworms -

1. True Armyworm - Larvae may create a nuisance when moving in masses from place to place.

2. Fall Armyworm - See D.1.

E. Chinch Bug - None reported.

9. Natural Enemies:

A. White Grubs -

1. Japanese Beetle - Native predators of adults include pentatomids (Podisus spp.) and wheel bugs (Arilus cristatus (L.)). Larvae are fed on by various birds and small mammals. Of 14 parasitic insects introduced from Japan, only the tachinid fly Istochaeta aldrichi (=Hyperecteina aldrichi = H. cinerea) (which parasitizes adults) and the tiphiid wasp Tiphia popilliavora (which parasitizes larvae) are promising (in areas of heavy infestation only) (Pfadt 1978). The most useful biocontrol agent is the bacterium Bacillus popillae, which causes milky disease in grubs. Bacillus popillae is available commercially (see Page XXXIX-22).

2. Black Turfgrass Ataenius - Black turfgrass ataenius larvae are attacked and killed by a milky spore disease Bacillus. The causal agent is not the same as that which infects Japanese beetle larvae (Niemczyk 1981).

3. May or June Beetles - Grubs are consumed by hogs, poultry, birds, and small mammals. Larvae are parasitized by wasps (Tiphia spp., Myzinium spp., and Pelecinus polyturator), the fly Pyrgoa undata, fungi (Cordyceps spp.), and the bacteria Bacillus popilliae and B. lentimorbus. The bacteria are of little use in biocontrol (see Page XXXIX-22).

B. Mole Crickets - Information is not available.

C. Sod Webworms - Many small mammals and birds consume larvae. Numerous parasitic flies and wasps are known to attack sod webworms, but are not effective in

controlling outbreaks. The fungus Beauveria bassiana and the bacterium Bacillus thuringiensis (B.t.) infect sod webworm larvae; B.t. is recommended as a biocontrol agent against 1st and 2nd instar larvae (see Page XXXIX-23).

D. Armyworms -

1. True Armyworm - Larvae may be effectively controlled by the parasitic tachinid fly Winthemia quadripustulata. Other insect parasites include Telenomus minimus (an egg parasite); the braconid wasps Apanteles laeviceps, A. marginiventris, and A. militaris; ground beetles; sphecid wasps; birds; toads; domestic fowl; and small mammals (e.g., skunks).

2. Fall Armyworm - Parasites of eggs and larvae include the ichneumon wasp Ophion bilineatus; the braconid wasps Chelonus texanus, Meterous laphygmae, and Apanteles spp.; Trichogramma minutum; Euplectrus wasps; and the tachinid flies Winthemia quadripustulata and W. rufopicta. Predators include ground beetles, birds, and many small mammals.

E. Chinch Bugs - The most important natural enemy of these pests is the "white fungus disease" agent Beauveria globulifera. Long periods of rain favor this natural control agent. Also, the wasp Eumicrosoma beneficum may parasitize up to 50% of the chinch bug eggs in favorable localities.

III. MANAGEMENT OF TURF INSECTS

1. Population Monitoring Techniques:

A. White Grubs -

1. Japanese Beetles - A standard golf-course cup-cutter (4 1/2" in diameter) can be used to obtain turf samples for visual examination for grubs. After grubs are counted, the turf and soil plug can be replaced in the hole made by the cutter. Multiplying the count from one such sample by 10.15 gives an estimate of the number of grubs per square foot of turf. Several samples should be taken throughout an area of suspected infestation and the results averaged. Alternatively, use a spade to cut three sides of a one foot square of turf to a depth of 4-5 inches in the soil, and carefully fold back the turf using the uncut edge as a hinge. Scrape the dirt from the roots to expose the larvae and count the number of grubs found.

   Counting adult beetles is not useful, except that a heavy beetle infestation seen during one summer indicates a possible heavy grub infestation in the next year. Adults can be monitored using traps (e.g., Bag-A-Bug® and Super Trap Attack®). Most traps use a floral lure which smells strongly like flowers. Some traps may also use a sex pheromone as attractants. Those traps that have both types of attractants collect 30% more males than traps with just a floral lure (J.L. Hellman, personal communication). Traps help indicate adult activity in your area, and a large number of traps in an area may actually help reduce beetle populations.

2. Black Turfgrass Ataenius - Use the cup-cutter or spade methods as described in A.1. To determine when adults will begin laying eggs, visually inspect golf greens for adult beetles. In addition, the egg-laying period for the first annual generation has been found to correspond to the full-bloom periods of the Vanhoutte spirea and the horse chestnut, and the first-bloom period of the black locust. Second-generation egg-laying coincides with the blooming of the rose-of-Sharon (Hibiscus syriacus). Observation of these indicators may be used as a basis for applying controls. Adult beetles may be monitored with a UV-light trap (Niemczyk 1981).

3. May or June Beetles - The most effective monitoring technique is the cup-cutter method as described in A.1. Adult activity may be monitored with light traps.

B. Mole Crickets - Infested areas may feel "fluffy" underfoot due to the tunnels under the thatch. Suspect turf can be visually inspected for the presence of entrance holes (1/2 - 1" in diameter) in the soil or thatch layer. A quantitative estimate of mole cricket populations is obtained using the soap flush technique. A solution of 1-2 ounces of liquid dishwashing soap in 2 gallons of water is sprinkled over a marked 4 ft^2 area of turf. The soap irritates the insects, driving them to the surface. All mole crickets coming to the surface in the three minute period following treatment are counted (and the total is divided by four to convert to number per square foot) (Short et al. 1982).

C. Sod Webworm - Feeding holes made by birds in infested grass should trigger a search for larvae or for green frass pellets which the larvae leave. Use the soap flush monitoring technique described for mole crickets to estimate the number of webworm larvae per square foot. Adult activity, monitored with light traps or by observation of adult flight during mowing operations, can be a useful predictor of potential heavy infestation. Damage usually becomes evident 2-3 weeks after heavy moth flight has been observed.

D. Armyworms -

1. True Armyworm - See C. Light traps work best for monitoring adult activity.

2. Fall Armyworm - See D.1.

E. Chinch Bugs - Droughty areas should be visually inspected for the presence of adults and nymphs on leaves and in thatch. Suspect areas should be monitored with the water float technique. Remove both ends from a large coffee can and push one end of the can 2-3" into the turf in the suspected infestation site. Fill the can with water and count all chinch bugs which float to the surface after three minutes. A typical (2 lb) coffee can samples an area of 31.4 in^2; convert the results to number per square foot by multiplying by 4.58. Adjust the conversion factor as needed for cans of different dimensions.

2. Threshold/Action Population Levels:

The following threshold values (J.L. Hellman, U. Maryland, personal communication; Short et al. 1982) were developed as guidelines for the management of valuable turf areas where very little damage is tolerated, such as golf courses and home lawns. In the NPS, valuable turf with very low damage tolerance might include monument grounds, historic sites, and very high use grass. The number of pests required to produce significant damage to a particular site varies with weather conditions, host plant vigor, grass variety, and use patterns. Heavy use sites require more maintenance than lower use sites, because the greater stress placed on the turf makes it more susceptible to damage by turf insects. For turf areas that can tolerate a greater amount of damage before management measures are needed, the thresholds suggested below can be adjusted upward in accordance with the importance of the turf and the other factors discussed above. Each park manager should set threshold/action levels for any particular situation by correlating observed turf damage with pest counts determined by the methods described in Section III-1. After a few years test sampling, a fairly good static threshold could be determined for each site.

A. White Grubs -

1. Japanese Beetle - Control measures may be triggered when spring larval counts reach 15-20/ft^2, or when counts in the late summer or fall (when turf is dormant, thus more susceptible to injury) reach 6-10/ft^2.

   Ng et al. (1983) have developed a population sampling technique based on the cumulative number of 2nd instar larvae obtained in sequential 1 ft^2 samples (this was developed using the spade monitoring technique, Section III-A.1). Successive square foot samples are taken until the number of 2nd instar larvae encountered falls into one or the other of the two classes, treatment not required or treatment required. Use the treatment decision graph on Page XXXIX-29 to determine whether or not treatment is needed. This procedure assumes an action level of three or more 2nd instar larvae per square foot, and was designed for use in country club golf courses in New Jersey.

2. Black Turfgrass Ataenius - Severe injury to annual bluegrass may result when 30-50 larvae/ft^2 are present. Other grasses can apparently tolerate higher populations without showing symptoms.

3. May or June Beetles - See A.1.

B. Mole Crickets - Short et al. (1982) determined the economic threshold for this pest to be 2/0.1 m^2 for bahia grass lawns in Orlando, Florida.

C. Sod Webworms - Treatment may be triggered when larval populations reach 2/ft^2, since such populations can build up rapidly during the summer. The Defense Pest Management Information Analysis Center recommends treatment when larvae are present at a density of 12-16/ft^2 (Anonymous, date unknown).

D. Armyworms -

1. True Armyworm - Treatment may be triggered when May larval populations reach 1/ft^2.

2. Fall Armyworms - K31 and other fescues can suffer severe late-summer damage if larval populations reach 1/ft^2. Other grasses may be more tolerant.

E. Chinch Bugs - Twenty to 25 chinch bugs/ft^2 may cause severe damage, especially in hot, dry weather. Wet weather or irrigation may increase the plants' tolerance to bug injury.

3. Management Alternatives-Nonchemical:

The most cost and labor effective method of insect damage prevention, and the technique most likely to produce long lasting results is the use of resistant grass varieties. By selecting pest-resistant varieties adapted to the climate and soil characteristic of your region, many turf management problems can be reduced or prevented. Research in this aspect of turf management is ongoing; consult with your local Cooperative Extension Service Agent for the latest information on resistant varieties of turf recommended for your region and pest problems.

Good cultural practices help reduce or prevent turf insect pest problems. Healthy turf is better able to resist attack by insects and will show fewer signs of damage than turf that is stressed. Watering and fertilizing should be done in accordance with approved turf management practices for the type of grass you have and seasonal conditions encountered. Soil pH should be adjusted if necessary to maintain it within the recommended range. Mowing should be at the recommended height and frequency. Don't allow excessive thatch to accumulate, as this favors pests such as sod webworms,

armyworms, and chinch bugs. Contact your Cooperative Extension Service Agent for soil sample analysis and information on proper turf management techniques to use on the type of turf in your park.

Biological Controls -

A. White Grubs -

1. Japanese Beetle - Bacillus popillae (B.p.) is a spore-forming, soil-inhabiting bacterium that causes milky disease in Japanese beetle larvae. Grubs ingest the spores which infect the insects and eventually kill them. Commercial formulations of spores are available for application to infested soil as a powder. Some brands have other species of Bacillus included with the B.p. in the product. As these other species have no effect of Japanese beetle, be careful not to confuse them when applying the product. Best results will be obtained with products having 100 million viable spores of B.p. per gram. A single application of B.p. at label rates may provide effective control for up to several years, since B.p. can survive in the soil as spores when larvae are not present. However, it may take three years or more for B.t. treatment to become fully effective.

2. Black Turfgrass Ataenius - Although black turfgrass ataenius grubs are susceptible to a form of milky disease, it is not the same form as that which attacks Japanese beetle grubs and no commercial preparations are registered for use against these insects. If natural infections are present in a population (identifiable by opaque white larvae), the disease may spread through the population naturally.

3. May or June Beetles - Some authors (e.g., Davidson and Lyon 1979) reported that application of B.p. to infested soil provided some control of these pests. Others (e.g., Hellman personal communication, Niemczyk 1981 and personal communication) do not agree. Products containing B.p. and B. lentimorbus are available which may aid in controlling certain species.

B. Mole Crickets - Biological controls for these pests are not known.

C. Sod Webworm - Larvae under 1" in length (ie., 1st and 2nd instars) are very susceptible to the bacterium Bacillus thuringiensis (B.t.). Follow label directions when applying commercial formulations.

D. Armyworms -

1. True Armyworm - No biological controls are commercially available.

2. Fall Armyworm - See D.1.

E. Chinch Bugs - Biological control options are limited. If natural predators such as the big-eyed bug, or parasites such as Beauveria, are present, avoid application of chemical control measures.

Consult your Regional IPM Coordinator before implementing any biological control measures.

4. Management Alternatives-Chemical:

A. White Grubs -

1. Japanese Beetle - Diazinon may be applied to infested soil. Water thoroughly after application to move the insecticide into the soil. Diazinon may be adsorbed onto the thatch layer reducing the potential for contact with the target grubs, and has a residual life of 14 days or less.

2. Black Turfgrass Ataenius - See A.1.

3. May or June Beetles - See A.1.

B. Mole Crickets - Applying propoxur or diazinon sprays to infested lawns when nymphs are small (around June) can reduce cricket injury. Thorough irrigation before and after treatment is needed to move the insecticides into the soil. Various bait formulations containing 1/2 - 2% of these pesticides can be effective if applied in late June. No irrigation should be applied when baits are used. Application of granular diazinon formulations in the spring (once or twice) and up to monthly from July to September has provided useful levels of control.

C. Sod Webworms - The following insecticides are registered for sod webworm control: carbaryl, chlorpyrifos, and diazinon. Light irrigation after treatment may help move the pesticide into the thatch layer where webworms live.

D. Armyworms - Carbaryl and malathion are currently registered for armyworm control. Irrigation is not recommended, because armyworms emerge at night to feed, and contact the insecticide at that time.

E. Chinch Bugs - Diazinon or chlorpyrifos applied in April can kill overwintered bugs and reduce summer damage. A late summer application helps control the following year's spring generation. Irrigate following application to help move the insecticide into the thatch layer. Control may not be necessary when weather is cool and rainy, which favors the development of fungal diseases.

Consult your regional IPM Coordinator to determine which pesticides, if any, are best suited to your turf insects management program.

5. Summary of Management Recommendations:

Maintain turf in healthy condition by use of recommended turf management practices.

- Maintain soil pH within recommended range.
- Water at recommended rates and frequency.
- Use recommended fertilizers at correct rates and at appropriate times.
- Mow at recommended height and frequency.

If seeding or laying sod, consult turf experts concerning varieties resistant to local turf insect pests and adapted to local growing conditions.

Establish thresholds for pest species in your area, and maintain a regular turf insects monitoring program.

A. White Grubs -

1. Japanese Beetle -

a. Monitor for grubs in soil using the cup-cutter or spade method.

b. If damaging numbers of larvae are found, apply milky spore inoculum to infested turf areas. There may be a three year lag in control using milky spore.

c. If injury is severe, an application of a registered insecticide can be made in

August or September (when grubs are small, and most susceptible to injury).

2. Black Turfgrass Ataenius -

   a. Monitor larval populations as described in 1.a. Monitor adult activity by visual inspection coordinated with blooming of signal plant species.

   b. If damaging levels of larvae are present, consider use of a registered insecticide. Irrigate with at least 1/2" of water to move insecticide into the soil.

   c. If damaging levels of larvae are found in one season, treatment may be delayed until the following season to kill adults early in the year before they lay eggs. Apply diazinon just as adult beetles begin laying eggs. Use signal plants to time sprays; first generation adults begin laying eggs when horse chestnut and Vanhoutte spirea enter full bloom, and second generation adults begin laying eggs as the rose of Sharon (Hibiscus syriacus) blooms. Spray when the signal plants bloom. Alternatively, adult beetles can be monitored using UV-light traps.

3. May or June Beetles -

   a. Monitor as in 1.a.

   b. If monitoring shows damaging levels of grubs, apply milky spore bacteria to reduce future infestations.

   c. If necessary, registered and approved pesticides may be applied during the summer, when larvae feed near the soil surface.

B. Mole Crickets -

   a. Monitor for insects in areas showing characteristic "fluffy" damage (III.1.B) using the soap flush technique.

   b. If monitoring shows damaging levels of crickets, apply a registered and approved pesticide in May or June, when nymphs are small and feed close to the soil surface.

C. Sod Webworm -

a. Observe turf areas for small moths during mowing, hovering or darting over grass at night, or coming to light. Monitor for larvae using soap flush technique.

b. If damaging larval numbers are found, apply *B.t.* for control of small (<1 inch) larvae.

D. Armyworms -

a. Monitor for larvae using the soap flush technique.

b. See Sod Webworm.

E. Chinch Bugs -

a. Monitor suspected turf areas for damaging levels of infestation using the water float technique.

b. If damaging levels are found during the summer, apply chlorpyrifos or diazinon. Monitor for activity of overwintered adults in the spring and treat early (March or April).

Consult NPS IPM staff before applying any pesticide.

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V. PERSONAL COMMUNICATIONS

Dr. J.L. Hellmann
Department of Entomology
University of Maryland
College Park, Maryland 20742

(301) 454-3845

Dr. H.D. Niemczyk
Department of Entomology
Ohio Agricultural Research and Development Center
Wooster, Ohio 44691

(216) 263-3700

VI. JAPANESE BEETLE SEQUENTIAL SAMPLING DECISION GRAPH

This graph is from Ng et al. (1983), and is used to help determine whether or not treatment for control of Japanese beetle larvae is needed in valuable turf. See Page XXXIX-20 for a description of the method.

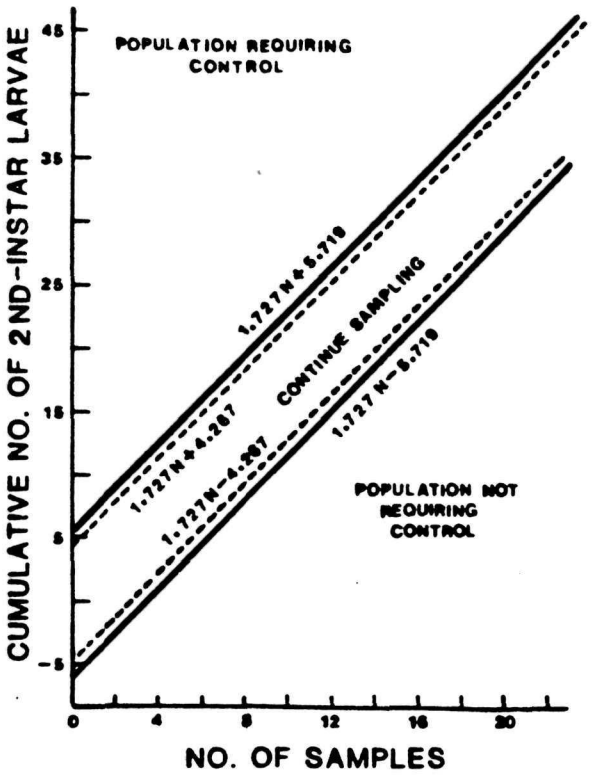

FIG. 1.—Sequential graph with decision lines for control measure on 2nd instars of the Japanese beetle in turfgrass. Confidence limits are 5% (solid line) and 10% (broken line).

NATIONAL PARK SERVICE
IPM Information Package

TURF WEEDS

Final Report

27 August 1984

Submitted To:

Gary H. Johnston
National Park Service
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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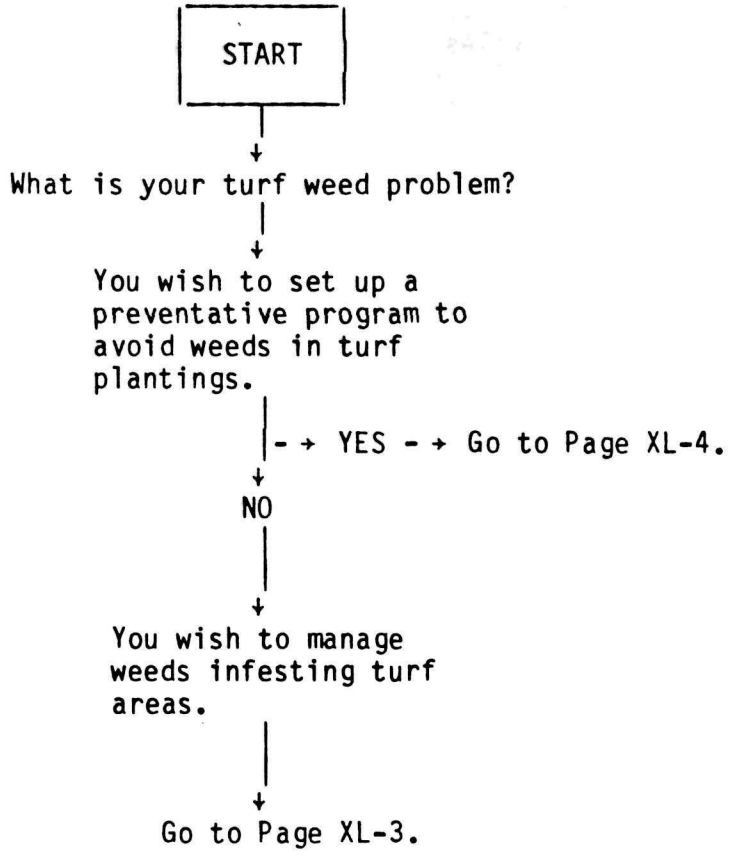
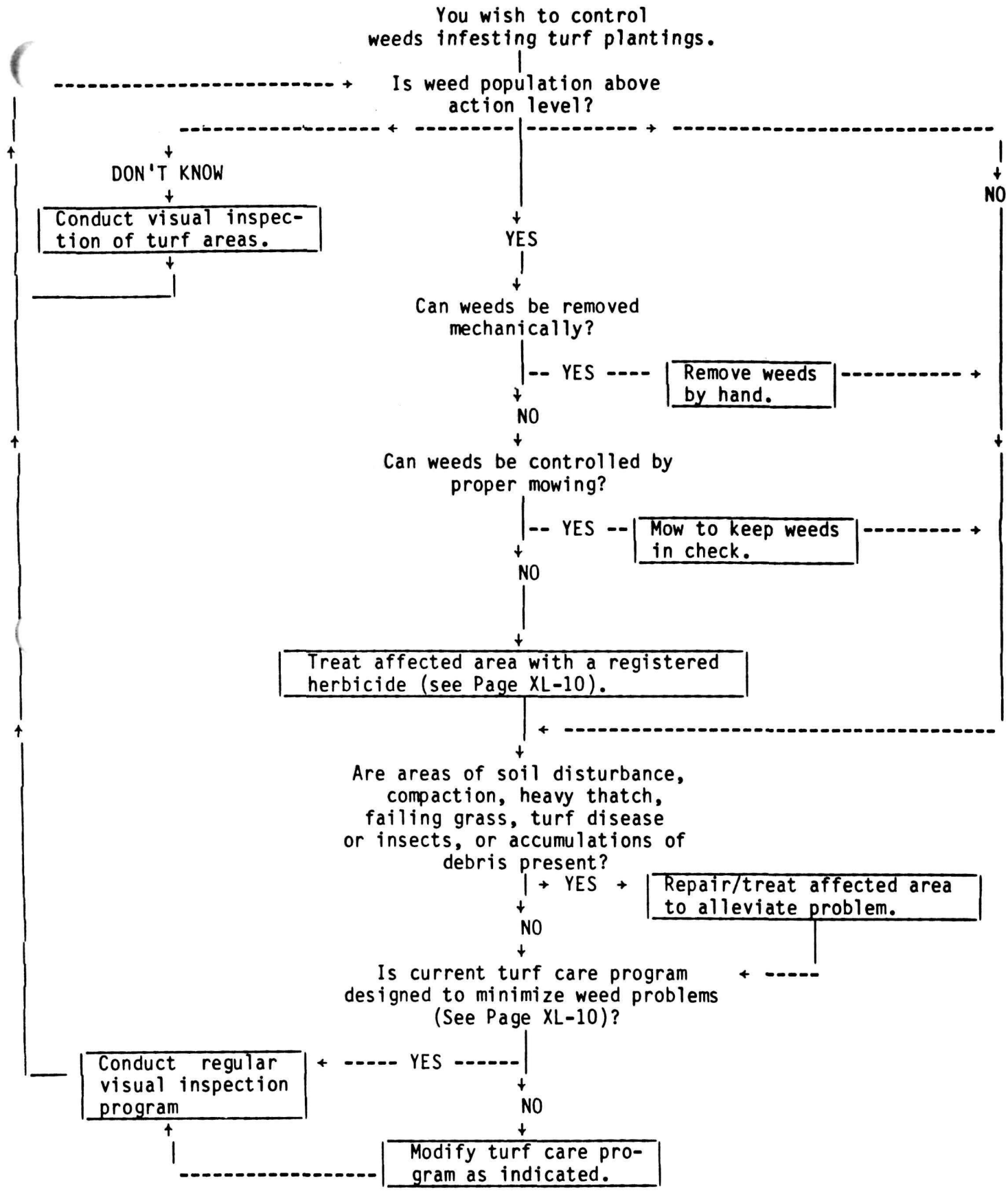
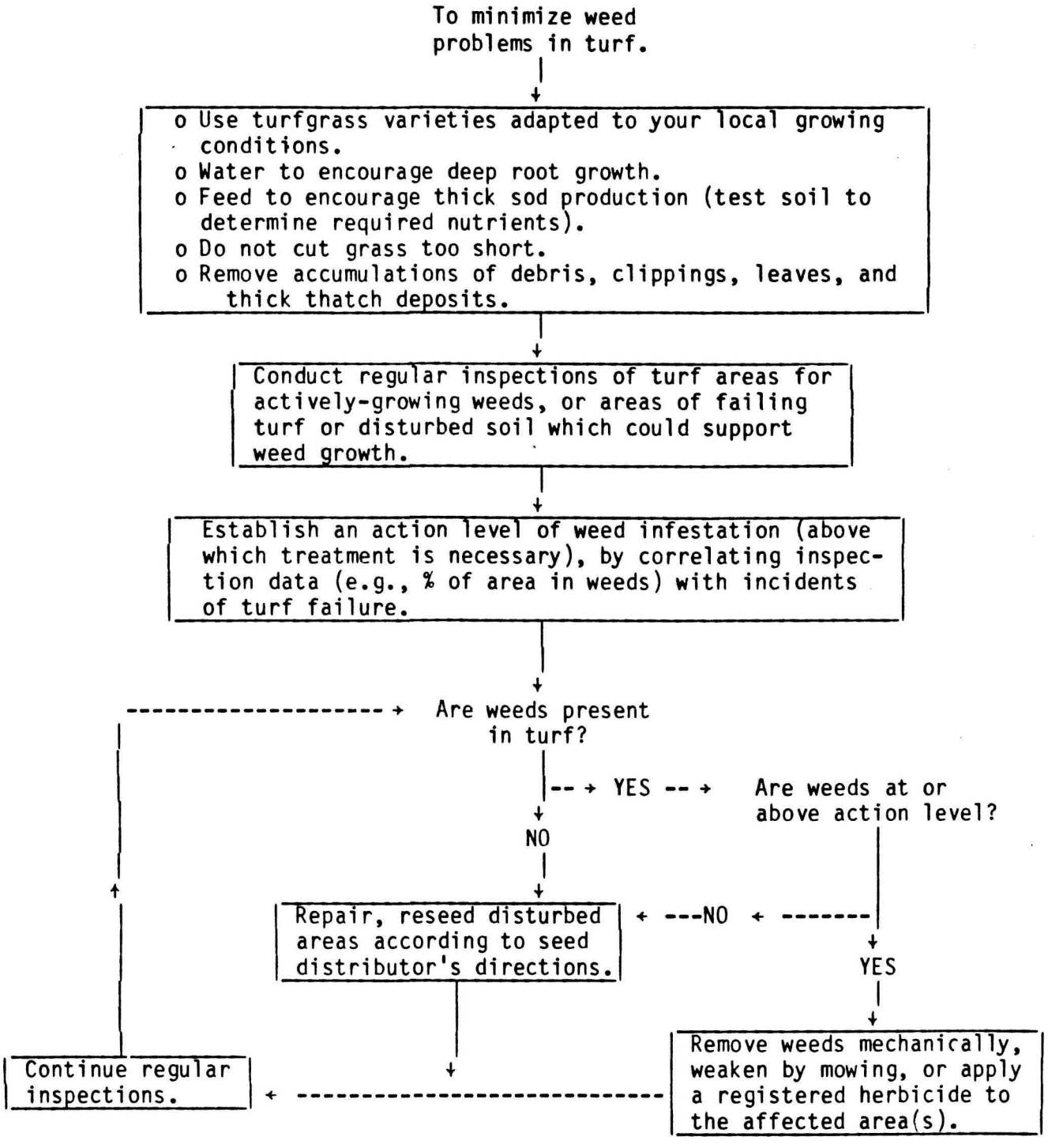
I. TURF WEED IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to EPA label instructions and be approved on an annual basis by the Director, NPS.




You wish to control weeds infesting turf plantings.
Is weed population above action level?
DON'T KNOW
Conduct visual inspection of turf areas.
YES
NO
Can weeds be removed mechanically?
-- YES ---- Remove weeds by hand.
NO
Can weeds be controlled by proper mowing?
-- YES -- Mow to keep weeds in check.
NO
Treat affected area with a registered herbicide (see Page XL-10).
Are areas of soil disturbance, compaction, heavy thatch, failing grass, turf disease or insects, or accumulations of debris present?
YES
Repair/treat affected area to alleviate problem.
NO
Is current turf care program designed to minimize weed problems (See Page XL-10)?
YES
Conduct regular visual inspection program
NO
Modify turf care program as indicated.


To minimize weed problems in turf.
o Use turfgrass varieties adapted to your local growing conditions.
o Water to encourage deep root growth.
o Feed to encourage thick sod production (test soil to determine required nutrients).
o Do not cut grass too short.
o Remove accumulations of debris, clippings, leaves, and thick thatch deposits.
Conduct regular inspections of turf areas for actively-growing weeds, or areas of failing turf or disturbed soil which could support weed growth.
Establish an action level of weed infestation (above which treatment is necessary), by correlating inspection data (e.g., % of area in weeds) with incidents of turf failure.
Are weeds present in turf?
YES
Are weeds at or above action level?
NO
NO
YES
Repair, reseed disturbed areas according to seed distributor's directions.
Remove weeds mechanically, weaken by mowing, or apply a registered herbicide to the affected area(s).
Continue regular inspections.

II. BIOLOGY AND ECOLOGY OF TURF WEEDS

1. Weeds Described:

Dicotyledonous (broadleaved) plants are those that have two cotyledons in each seed. They are characterized by broad leaves with netlike veination, tap roots and/or fibrous root systems originating from a primary root, and flower parts arranged in fours or fives (or multiples). Many broadleaf species (e.g., oak, maple) have woody stems, which increase in diameter by adding new vascular and cork cells developed from cambium cells. Some species (e.g., sunflower) only become woody in old parts of stems and roots; these are referred to as semi-herbaceous dicots. Species in which no woody development occurs (e.g., buttercup) are fully herbaceous.

Grasses are members of the plant family Gramineae. All grasses are monocotyledonous, have long, narrow leaves with parallel veins, fibrous root systems arising from adventitious roots, and flower parts in 3's. The flowers of grass species have no sepals or petals, and are wind pollinated. Many grasses produce underground stems (rhizomes) and runners (stolons). While some grasses spread rapidly to form large colonies (creeping or turf-forming habit; e.g., bentgrass), others form only single clumps (bunching habit; e.g., tall fescue).

Weeds are usually described as any plants growing where they are not wanted. Any broadleafed plant species, from a small herbaceous plant to a woody shrub, vine, or tree, may be considered a weed if it is growing in a turf planting. The description of each potential weed species is beyond the scope of this report. We suggest that you contact the USDA Cooperative Extension Service in your state for information on the most important weeds in your region. A list of useful pictorial weed guides is included in the Bibliography of this report.

2. Geographic Distribution:

Undesirable ("weed") plants will invade man-made environments such as turfgrass plantings wherever they are established.

3. Habitat: Weeds growing in turf are found where soil has been exposed or disturbed by traffic or planting activities; where the desired turf is weakened by adverse environmental conditions, diseases, or pests to the extent that it cannot compete for nutrients, water, or light with "weed" species; and where the desired grass is not as well adapted to its environment as are native or exotic "weed" species.

4. Hosts: Not applicable.

5. Life Cycles: The life cycles of turf weeds can be grouped into the following major types:

A. Summer annual weeds (e.g., morning glory, ragweed, large crabgrass, goosegrass) grow each spring or summer from seed. They mature, produce seeds and die in one growing season. Seeds generally overwinter before germinating the following spring. The majority of annual weeds are of this type. Some annuals (e.g., crabgrass) also root from leaf-stem junctions, forming dense colonies.

B. Winter annual weeds (e.g., field pepperweed, shepherds-purse, annual bluegrass, downy brome) germinate in the fall or late winter from seed, mature and produce seed during the following spring, and die in early summer. Seeds of most of these species are dormant during the spring.

C. Indeterminate annual weeds (e.g., common chickweed) may germinate and grow during any part of the year.

D. Biennial weeds (e.g., wild carrot, bull thistle, sweet clover) may germinate at any time during the growing season. They usually produce a radial cluster (rosette) of leaves lying close to the soil during the first season. During the second year, they produce flower stalks (using energy stored during the first season's growth), produce seeds, and die.

E. Perennial weeds live for three or more years. Some species may not flower the first year, and others may produce mostly nonviable seeds. While many perennials (e.g., curly dock, dandelion, common milkweed) spread primarily by producing seeds, many

others (e.g., field bindweed, silverleaf nightshade, bentgrass, quackgrass) spread both by seed and vegetatively (asexually). Vegetative spread may be by rhizomes, stolons, tubers, or rooting of stem nodes that touch soil.

6. Seasonal Abundance:

The seasonal abundance of weeds is related to their specific life cycles. Summer annuals grow from spring until fall, when they are killed by low temperatures. Winter annuals are present from fall to late spring, thus will not usually be found during the summer. Biennials grow during the spring, summer, and fall of their first year, survive over the following winter, and flower during the next growing season; therefore, some biennial stages are likely to be present at any time of the year. Perennials grow during each growing season. Their aboveground structures may die over the winter, or may remain viable but dormant.

7. Responses to Environmental Factors:

All plants that are able to settle on disturbed areas posses a great tolerance for soil disturbance and partial defoliation (Anderson, 1983). Their seeds may remain viable in the soil for several years until conditions favor germination. The seeds of many herbaceous weeds require high light levels and exposed mineral soil for germination. Weed species usually grow more vigorously than the turf they displace, and usually can grow under a wider range of conditions than the grass.

Many weed species possess efficient methods of seed dispersal (e.g., wind dissemination of light, winged or hairy seeds), and/or other means of rapid spread (e.g., rhizomes, runners, tubers). The particular group of species that an area will support will vary with the climate of the area, the nutrient levels in the soil, and the availability of light and moisture.

8. Impact of Weeds:

8.1 Direct Impact:

The direct impacts of weeds on turf areas include:

A. Competition with and replacement of turfgrass by better-adapted weed species.

B. Creation of unsightly patches of growth and/or dead areas when annuals overgrow turfgrass and then die (e.g., winter annuals).

C. Toxicity to humans and animals. Some common weeds are poisonous if consumed (e.g., nightshade, pokeweed, Johnsongrass), cause inflammation when touched (e.g., stinging nettle, poison ivy, oak, and sumac), or cause allergic reactions (e.g., common ragweed).

D. Visitor injury (due to spines or thorns of many weed species [e.g., sandbur]).

E. Necessity for increased expenditures for turf maintenance to control weed population.

8.2 Indirect Impact: Weeds can serve as secondary hosts for microbes and insects which may attack desirable turfgrasses. Weedy areas may also become habitats for rodents and arthropods (e.g., rats, ticks, mites, mosquitoes, biting flies) which might attack humans and domestic animals, and/or carry diseases affecting humans and animals.

9. Natural Enemies: Weed species are subject to attack by many natural enemies, including herbivorous mammals, reptiles, birds, and insects; disease organisms such as fungi, bacteria, nematodes, viruses, and spiroplasmas; and allelopathic plants (which produce chemicals inhibitory or toxic to the weed). Plant species better adapted than the weed to the particular growing site may out-compete and replace a weed species. While certain antagonistic organisms have been used for biocontrol of specific weeds in aquatic and agricultural situations (e.g., biocontrol of waterhyacinth by three exotic insects and fungus Cercospora rodmanii), no adapted biocontrol agents are currently available commercially for control of weeds in turf.

III. TURF WEED MANAGEMENT

1. Population Monitoring Techniques:

Integrated weed management is not yet a highly developed discipline. To date, the best technique for monitoring weed populations is visual observation. Conduct regular (weekly) visual inspections of grass areas for:

Actively growing weeds;

Sites of soil disturbance (compaction, exposure of open soil, flooding, drought);

Areas of heavy thatch (which decreases turfgrass vigor and benefits shallow-rooted weeds);

Areas of grass failure due to tree competition (especially from shallow-rooted trees);

Areas where grass has been mowed too short (which can weaken the plants and make them less competitive);

Areas of insect and disease attack;

Localized dry spots;

"Dog Blight", caused by animal urine; and

Accumulations of leaves or other debris which may smother the grass and provide new areas for weed growth.

Monitoring for actively growing weeds should be done throughout the growing season. Less frequent inspections should be made during the winter to identify sites of soil disturbance or other adverse effects which may give rise to weed problems next season.

All monitoring results should be completely and accurately reported by site and date, so that future surveys will cover the same areas, allowing the site manager to develop a weed history of his area. This will enable him/her to more accurately predict future weed problems.

2. Threshold/ Action Population Levels:

It is extremely difficult to set specific threshold population levels for weeds in turf, since the problems caused by weeds are largely aesthetic, rather than medical or economic. Each park manager should establish threshold and action levels for his/her own area by maintaining records of weed populations in all turf areas. Action levels will be lower in high-use areas (e.g., golf course greens and fairways) than in low- or medium-use sites (e.g., parking areas). An additional factor which should be considered is the type and cost of treatments which would be triggered when the appropriate action level (that weed population requiring control measures to prevent the threshold level from being reached) is observed.

3. Management Alternatives-Nonchemical:

A. Cultural methods - Turf management practices which increase the health, density, and general vigor of grass will discourage weeds through competition. Such methods include:

1. Use of grasses which are adapted for the specific planting area (i.e., climate, light intensity) and type of use (e.g., heavy traffic) will promote the best possible sod development.

2. Use of grass seed, sod, topsoil, and mulches that are free of weed seeds.

3. Maintenance of optimum soil conditions for grass through adequate feeding and liming of turf based on soil testing.

4. Regular, deep watering (to a depth of 5 to 8 inches) when grass begins to show signs of wilting will prevent the development of shallow root systems and weak turf. Frequent, shallow watering encourages the germination of some weed seeds and should be avoided.

5. Removal of debris - Leaves or other accumulated debris should be removed from turf. Such accumulations can smother or shade the grass, allowing weeds to grow in its place. Heavy thatch should be mechanically removed, as well.

B. Mechanical methods -

1. Removal - Established weeds can often be pulled from the soil by hand. Some weeds with long tap roots (e.g., buckhorn plantain) cannot be totally removed by pulling; remaining root fragments may resprout.

2. Mowing - Frequent mowing will prevent annual weeds from producing seeds, and will weaken perennial weeds by removal of foliage. Lawns should be cut no shorter than 1 3/4-2 inches in height to prevent weakening of the grass.

3. Cultivation - Before seeding an area with turfgrass, shallow cultivation (after emergence of most annual weeds) can eliminate species that would be difficult to control after turf establishment.

C. Biological control - No biological control agents have been approved by the U.S. Environmental Protection Agency for use in turf plantings. However, the use of nonchemical methods (or chemicals with a limited host range) for control of insects and other pests will permit naturally-occuring weed controls to operate at maximum effectiveness.

Management Alternatives-Chemical:

Information on selection of turf herbicides can be obtained from your regional IPM Coordinator, your local USDA Cooperative Extension Service agent, your local state university turf specialist, or from publications such as the following:

A. "Suggested guidelines for weed control", USDA Agriculture Handbook #565;

B. "1985 Weed Control Mannual", Meister Publishing Company, 37841 Euclid Ave., Willoughby, OH 44094 (revised annually); and

5. Summary of Management Recommendations:

A. In established plantings:

1. Maintain optimum soil conditions for grass through regular soil testing and adequate feeding.

2. Water regularly, to a depth of 5-8 inches, when grass begins to show signs of wilting. Frequent, shallow watering promotes weed establishment.

3. Remove debris and heavy thatch from turf.

4. Reduce soil compaction through aeration and top dressing with sand or organic matter.

5. Mow no shorter than 1 3/4-2 inches, to prevent weakening of grass and germination of weed seeds.

6. Inspect turf regularly for weeds and disturbed areas. Set tolerance levels for weeds. If weed populations exceed tolerance levels, remove weeds mechanically, or mow to reduce weed vigor. Use a registered herbicide if necessary. Repair and reseed disturbed areas. Use grass varieties adapted to the growing conditions when reseeding.

B. In new plantings -

1. Plant turfgrass varieties that are adapted to the growing area, and resistant to diseases and insects. Use planting materials that are free of weed seeds.

2. When preparing the area for planting, allow annual weed seeds to germinate; then cultivate to kill young plants.

3. During establishment of turf, inspect regularly for weeds. Remove weeds found.

4. Follow program in A. to maintain turf once established.

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Consult your local USDA Cooperative Extension Service agent, State University, or regional IPM coordinator for weed identification guides and services specific for your area.

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NATIONAL PARK SERVICE
IPM Information Package

WATER HYACINTH

Final Report

7 December 1984

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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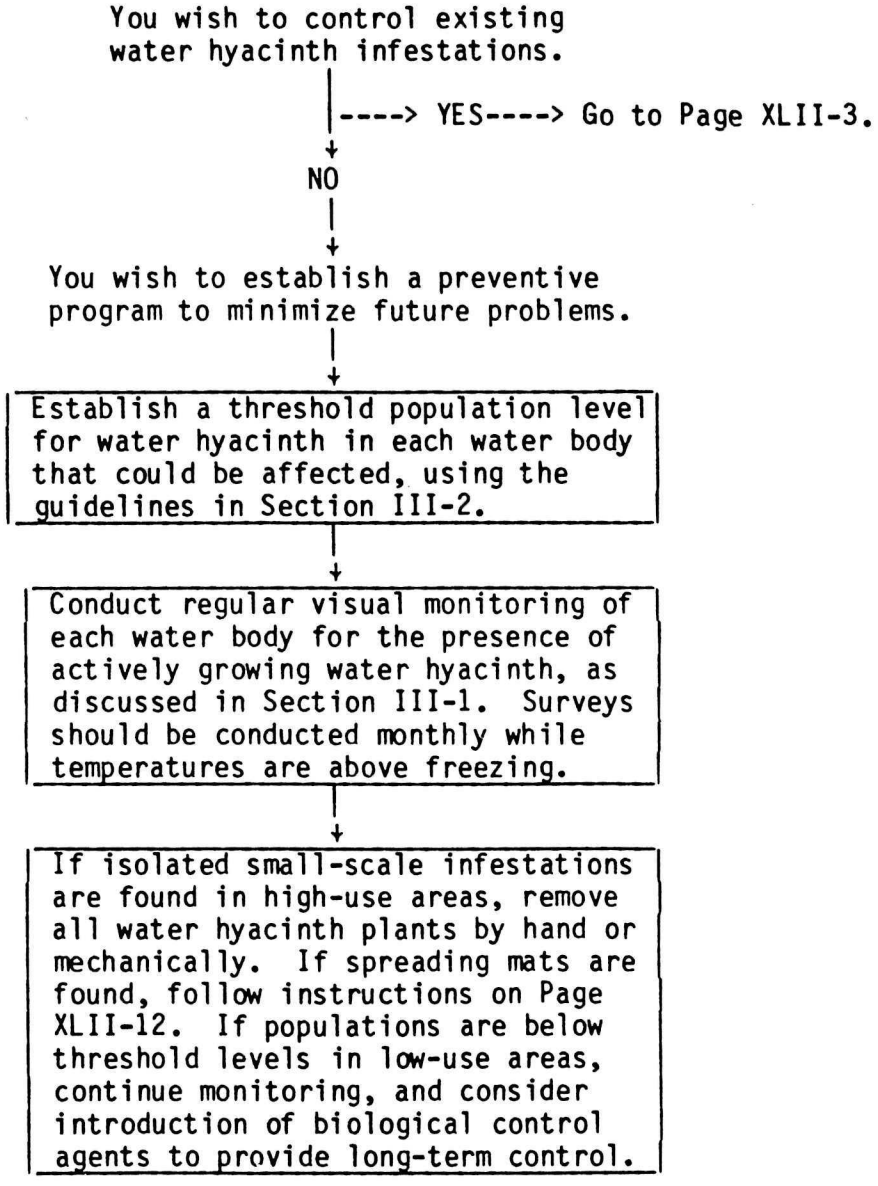
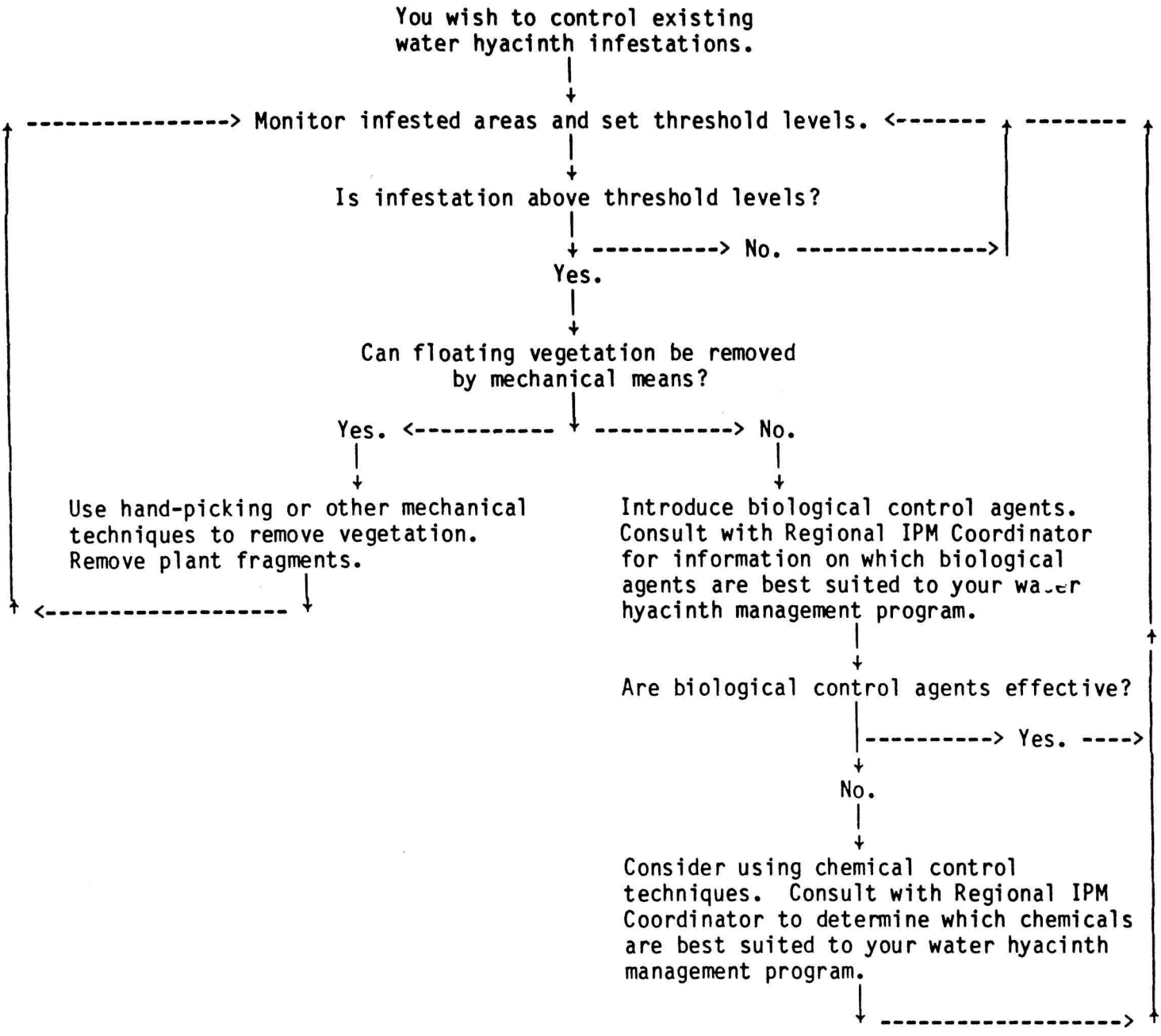
I. WATER HYACINTH IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




You wish to control existing water hyacinth infestations.
Monitor infested areas and set threshold levels.
Is infestation above threshold levels?
No.
Yes.
Can floating vegetation be removed by mechanical means?
Yes.
No.
Use hand-picking or other mechanical techniques to remove vegetation. Remove plant fragments.
Introduce biological control agents. Consult with Regional IPM Coordinator for information on which biological agents are best suited to your water hyacinth management program.
Are biological control agents effective?
Yes.
No.
Consider using chemical control techniques. Consult with Regional IPM Coordinator to determine which chemicals are best suited to your water hyacinth management program.

II. WATER HYACINTH BIOLOGY AND ECOLOGY

1. Species Described:

Water hyacinth (*Eichhornia crassipes* [Mart.] Solms) is a floating aquatic monocot belonging to the family Ponterderiaceae. The water hyacinth plant varies in size from 1" to 4' in diameter. A submerged rhizome and crown is surrounded by a rosette of dark green, leathery, circular to elliptical leaves which may be up to 8" long and 6" wide. Each leaf stalk is spongy, and may have a bulbus, expanded central portion, especially in small plants or plants in sparse populations (Aurand, 1982). The growth of water hyacinth shoots is monopodial (shoots branch off from a main stem). A branching, fibrous root system arises from the rhizome. The feathery-appearing roots may extend 6-24" below the water surface, but do not contact the hydrosoil.

Water hyacinth produces large numbers of submerged stolons, which produce daughter plants. In a suitable environment, actively-growing plants may double in number every two weeks (Gangstad, 1978), producing large floating mats of interconnected plants which can completely cover small ponds, lakes, or slow-flowing streams.

An upright stalk containing several light blue to violet flowers 2" in diameter is produced from the center of each plant. Flowers consist of 6 petals, the uppermost of which bears a yellow patch. In tropical areas pollination is by insects, but in subtropical and temperate areas such as the U.S. *E. crassipies* is self-pollinated (Gangstad, 1978). After pollination, flower spikes bend at three points, so that seed capsules develop and release their seeds underwater. See Tarver, *et al.* (1979) for photographs and additional details of water hyacinth morphology.

2. Geographic Distribution:

Water hyacinth is a native of South America. It was reportedly introduced into the United States at the New Orleans, LA, Cotton Exhibition of 1884, where plants imported from Venezuela were given as souveniers (Aurand, 1982). By 1900, the weed had spread through most of the waterways of Louisiana. A visitor to the exhibition took several plants to Florida, for use as ornamentals, and by 1949, 63,000 acres of Florida water were covered by water hyacinth. Other states in which the weed occurs are Alabama, California, Georgia, Hawaii, Mississippi, North Carolina, South Carolina, Texas, and Virginia.

3. Habitat: Water hyacinth is a free-floating plant which lives in standing or slowly moving fresh water. It requires relatively high light levels and above-freezing temperatures. Wind and currents may move the weed throughout a water body, or from one water body to another.

4. Hosts: Not applicable.

5. Life Cycle: Water hyacinth reproduces both sexually and asexually in the U.S. Self-fertilization of flowers can result in the production of 45,000,000 seeds per acre of water hyacinth. However, only 5% of those seeds may germinate (Gangstad, 1978), due to infertility and/or the absence of proper conditions for germination (Barrett, 1980). Seeds are released underwater, and may fall to the hydrosoil or remain trapped in the roots of the parent plant. Fertile seeds may remain viable for up to 7 years, but only will germinate after an exact process of drying and rewetting has taken place (Wolverton, no date).

Once a plant is established, it is capable of extremely rapid growth under favorable conditions. The most effective and common means of spread in the U.S. is the production of daughter plants from underwater stolons growing from the crown of the parent plant. One plant can produce up to 300 interconnected offspring in less than a month. In a single growing season, 10 plants could produce enough offspring (about 600-700 thousand) to completely cover an acre of water surface (United States Army Corps of Engineers, 1973). Such growth results in the formation of water hyacinth mats, which can spread at an average rate of 2 feet each month (Aurand, 1982).

6. Seasonal Abundance: Water hyacinth attains maximum standing crop in May and June, but will continue to grow as long as air and water temperatures remain favorable (Center and Spencer, 1981).

7. Responses to Environmental Factors: Water hyacinth is the fastest growing plant known to man (Wolverton and McDonald, 1977). It can grow in water ranging in temperature from 53°F to 100°F, but optimum growth occurs within the range 71°F to 95°F (Knipling et al., 1970). Seed germination is optimal at water temperatures of 82°F to 97°F, and is retarded at water temperatures below 50°F. Water hyacinth plants can be killed by repeated exposure to subfreezing temperatures. These plants have a high light

requirement, and cannot grow well under forest canopies. Growth is poor in acid, soft, or saline (over 0.6 ppt) water. Water hyacinth plants may be spread by wind and/or water currents. Broken stems or crowns are capable of regrowth, so that mechanical damage may actually increase the plant population.

8. Impact of Water Hyacinth:

8.1 Direct Impact: The major impact of water hyacinth is the clogging of water bodies by floating mats of weeds, reducing the usefulness of the water for swimming or boating. Since water hyacinth is such a rapid grower, it may displace or eliminate desirable plant species. The root systems of water hyacinth may remove large quantities of nutrients from the water in which they grow.

8.2 Indirect Impact: The major indirect impact of water hyacinth is the displacement of animals and plants from infested waters, due to overgrowth of the weed. In addition, mosquitoes or other insects of public health or nuisance importance may breed in the water hyacinth mats. Water hyacinth may also cause the suppression of other undesirable aquatic weeds (e.g., alligatorweed or waterlettuce) (Aurand, 1982).

Water hyacinth removes nutrients, pesticides, and heavy metals from the water. NASA uses water hyacinth in its sewage treatment lagoons in Bay St. Louis, Mississippi, and has helped to establish wastewater treatment programs using water hyacinth in numerous localities throughout Mississippi, Louisiana, Florida, and in San Diego, California (W. Wolverton, personal communication). In these treatment systems, water hyacinth greatly improves the quality of the effluent (Wolverton and McDonald, 1979a; McDonald and Wolverton, 1980). The overgrowth is harvested and can be used for compost, human and animal food, and for the generation of biogas to produce electricity (Wolverton and McDonald, 1979b; Wolverton and McDonald, 1981).

9. Natural Enemies:

A. Insects -

1. Water hyacinth weevils - Neochetina eichhorniae Warner (the mottled water hyacinth weevil) and N. bruchi Hustache (the chevroned water hyacinth weevil) are native to Argentina, Bolivia, and Trinidad. Adult beetles are nocturnal feeders that produce 1/8" feeding

scars (on leaf blades and petioles) in which eggs are laid. Eggs may also be laid in injured leaf tissues. Larvae mine within the petioles during their five developmental instars, then migrate to submerged roots to pupate. Adults begin feeding immediately after emerging. The tunneling and feeding activities of the insects may completely kill stems and leaves. In addition, pathogenic microbes infect plant tissues exposed by larval tunneling, often resulting in leaf death or abcission. These insects have been introduced into the U.S. as biocontrol agents (Theriot, 1982)(see Section III.3).

2. Water hyacinth moth - Newly hatched larvae of the Argentine pyralid moth Sameodes albiguttalis (Warren) feed on the surfaces of leaves and petioles, creating irregularly shaped lesions. Older larvae burrow into petioles (especially inflated petioles) and feed internally. Water accumulates in the damaged area, leading to waterlogging and submerging of infested leaves. Newly hatched larvae begin feeding just below the epidermis (outer layer) of the petioles, and feeding damage becomes evident after 1-2 days. Some may burrow into the youngest petiole and excavate the end of the rhizome, destroying the apical bud, halting development of the shoot. Fifth instar larvae may damage several petioles, exiting and entering at contiguous petiole bases (Center, 1981). This species has been released in the U.S. as a biocontrol agent (See Section III.3.B.1).

3. Arzama densa - The native American noctuid moth A. densa (Walker) attacks water hyacinth and pickerelweed. Larvae tunnel into petioles and crowns, producing extensive feeding damage (Cofrancesco, 1982). Effective biocontrol of water hyacinth has not been achieved using A. densa, due to the presence of parasites which attack larvae during the later (4-7) instars (Cofrancesco, 1982), but the moth is being considered for use in Hawaii where it could be introduced free of parasites (E. Theriot, personal communication).

5. Water hyacinth mite - The mite Orthogalumna terebrantis Wallwork attacks water hyacinth in Florida and Louisiana, and may have been introduced into the U.S. with the weed (Del

Fosse, 1978). The mite bores feeding galleries beneath the epidermis of leaves, causing moderate to severe damage. The biocontrol potential of this species in the U.S. is not known, but Sanders et al. (1982) reported only slight impact on infested plants in Panama.

B. Fungi - Cercospora rodmanii Conway - This fungus was isolated from diseased water hyacinth leaves in a reservoir in Florida in 1973. The pathogen causes symptoms ranging from small, dark spots on the leaf blade or petiole to destruction of the entire leaf and petiole. C. rodmanii is specific for E. crassipes. Abbott Laboratories, Chicago, IL, is developing a commercial formulation of the fungus (Pennington and Theriot, 1983). Theriot (1981) has reported successful control of E. crassipes using this agent.

C. Mammals - The manatee (Trichechus manatus L.) is a large (up to 15 feet long and 1300 lbs in weight), roughly torpedo-shaped, slow-moving, social aquatic mammal commonly known as the "sea cow." Manatees live in warm, shallow coastal waters of Florida and range from Texas to southern North Carolina. Manatees are listed as an endangered species in the U.S., and are relatively rare even in Florida, where there are only about 1000 individuals. They feed on aquatic plants, consuming as much as 100 lbs of vegetation each day. Water hyacinth is a favored food of manatees. In the U.S., research was conducted in the 1960's on the use of manatees to control aquatic weeds, but the status of the manatee as an endangered species has made it doubtful that they will be practicable biocontrol agents (Blackburn and Andres, 1968; Gluckman, 1983; McGehee and Zeiger, 1977). However, aquatic weed managers should keep in mind the potential effects on water hyacinth of manatees in any areas where they occur, and the influence of water hyacinth control measures on manatee populations.

III. WATER HYACINTH MANAGEMENT

1. Population Monitoring Techniques:

The only effective technique for monitoring water hyacinth population levels is periodic visual inspection of water bodies for the presence of water hyacinth plants. Surveillance programs are based on remote sensing and/or ground reconnaissnace. False-color infrared aerial photography is highly effective in water hyacinth survey programs (Leonard, 1982). The photographs are taken at a scale of 1:12000 in the spring and fall of each year. The distribution of water hyacinth is traced onto transparent base maps and their area of coverage calculated. The interpretation of false-color infrared photographs requires trained personnel.

2. Threshold/ Action Population Levels:

Standardized threshold levels for water hyacinth populations have not been formulated. The Army Corps of Engineers, Environmental Protection Agency, and state and local agencies concerned with water hyacinth management base their treatment decisions on a cost/benifit analysis. A unique threshold level must be established for each water body, based on considerations such as the type and size of the water body (site), the activities (e.g., fishing, swimming, boating) which occur at the site, the numbers and types of desirable flora and fauna inhabiting the site, and so on. Such information can be correlated with inspection data (e.g., population levels and conditions, extent of coverage) to produce the threshold and action population levels for each water body. In general, high-use aquatic sites (e.g., swimming beaches, boat docks) will be more sensitive to water hyacinth infestations than will low-use sites (e.g., wildlife preserve or shore-only fishing areas). In addition, at sites where the weed population is under attack by predators or parasites, allowing natural controls to operate may produce more effective long-term control than would the application of additional control measures. In such areas, a higher threshold level may be beneficial.

The U.S. Environmental Protection Agency has developed a computerized "expert system" for the determination of threshold levels and the design of programs for water hyacinth management in water bodies in several Southeastern states (Rodgers et al., 1983). Use of the system requires the input of information concerning the location and type of the affected water body, available water quality data, water uses, growing

season data, infestation area, and the known or reported effects of the infestation on water body uses (Anonymous, 1983). The system ("Decision Matrix for Integrated Control of Aquatic Weeds") is currently useable on Apple III® computers. For information concerning the availability of the system, contact:

Charles D. Reese
Office of Pesticide Programs
U.S. Environmental Protection Agency
Washington, D.C.

3. Management Alternatives - Nonchemical:

A. Mechanical harvesting - Mechanical harvesting is recommended for the following situations:

1. Where shallow zones of ponds or lakes are covered by dense stands of weeds;

2. When the use of other methods is undesirable because of potential adverse impacts on water uses, animals, or plants;

3. Where nuisance weeds are resistant to herbicides;

4. Where nutrient loading from decomposing weeds left in the water could promote eutrophic conditions; and

5. In small lakes, ponds, or embayments (less than 100 acres).

Mechanical harvesting may not be beneficial where internal obstructions in the water body would impair harvesting, where shallow areas would be disturbed by the procedures, or where weed fragments could be dispersed by currents or wind, compounding the weed problem (Rodgers et al., 1983). A disadvantage of mechanical harvesting is its high cost relative to the use of chemical or biological control measures (Canellos, 1981).

Mechanical harvesting methods include:

1. Hand removal - Small-scale infestations can be eliminated by handpicking the weeds, which can then be transported to an on-shore disposal site. While this technique is labor intensive, it could be incorporated into the survey process, allowing small infestations to be eliminated as soon as they are discovered.

2. Harvesting machines - Mechanical harvesting machines generally consist of a boat-mounted reciprocating cutting and collecting system, which may feed cut material into a conveyor for shore dumping, or may throw cut material onto the shore, or may not collect material (in this case, an additional boat with rakes or other collecting devices is required). Harvesters cost $6,000 to $170,000 (1982 basis), and are available from the following manufacturers:

   a. Aquamarine Corp.
      Box 616
      Waukesha, WI 53186

   b. Altosar Aquatic Weed Harvesters
      3147 Losey Blvd.
      LaCrosse, WI 54601

   c. Hickney Co.
      913 Cogswell Drive
      Silver Lake, WI 53170

   d. Limnos, Ltd.
      22 Roe Ave.
      Toronto, Ontario, CANADA

   e. Mudcat Division
      National Car Rental Co.
      P.O. Box 16247
      St. Louis Park, MN 55416

   f. Mariner Water Weed Harvesters
      104 Locust St.
      Polmyra, WI 53156

B. Biological Control -

   1. Insects - The exotic water hyacinth weevils Neochetina bruchi and N. eichhorniae have been released at numerous sites in the U.S. and appear to be spreading throughout most of the range of the plant (Gangstad, 1978 and personal communication). The insects can be obtained from the Aquatic Plant Operations Support Center (APOSC), U.S. Army Corps of Engineers, P.O. Box 4970, Jacksonville, FL 32201. APOSC does not charge for control agents (except for shipping and handling fees). The Argentine water hyacinth moth (Sameodes albiguttalis) has been released and is established in southern Florida (Center, 1982) and Louisiana (Aurand, 1982). Field studies

of the effectiveness of this moth as a biocontrol agent are ongoing. For information on the efficacy and availability of S. albiguttalis, contact:

Ted D. Center
USDA Aquatic Plant Management Lab
3205 SW College Ave.
Ft. Lauderdale, FL 33314.

2. Pathogens - While numerous fungal pathogens of water hyacinth have been found in worldwide searches, to date only the native species Cercospora rodmanii has been found to be an effective biocontrol agent in large-scale field tests (Pennington and Theriot, 1983). For further information on this agent, contact:

Edwin Theriot
U.S. Army Corps of Engineers
Waterways Experiment Station
Vicksburg, MS 39180.

3. Integrated Methods - Perkins (1977) found that water hyacinth plants treated with 2,4-D became more attractive to mottled weevils, increasing control. The effectiveness of herbicides against water hyacinth was found to be greater in plants attacked by the fungus Acremonium zonatum (Perkins, 1974).

4. Management Alternatives-Chemical: Several herbicides are registered for control of water hyacinth. Consult your regional IPM Coordinator to determine which, if any, of these herbicides is best suited for inclusion in your water hyacinth management program.

5. Summary of Management Recommendations:

A. Monitor all water bodies likely to be infested with water hyacinth, and set thresholds for each water body.

B. Where feasible institute mechanical harvesting techniques. Remove plant fragments to prevent regrowth.

C. Consider the introduction of biocontrol agents to provide long-term management of chronic infestations. Consult with your Regional IPM Coordinator or local

United States Army Corps of Engineers District personnel regarding the feasibility of biocontrol techniques in your water hyacinth management program.

C. Consider the use of a registered herbicide to provide rapid reduction of severe infestations. Consult with your Regional IPM Coordinator to determine which chemical, if any, is recommended for your water hyacinth management program.

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V. PERSONAL COMMUNICATIONS

E. O. Gangstad
Office of the Chief Engineer
U.S. Army Corps of Engineers
Washington, D.C.

Edwin A. Theriot
Research Team Leader
Biocontrol Team
U.S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

William Wolverton
National Space Technology Laboratory
National Aeronautics and Space Administration
Bay St. Louis, Mississippi

NATIONAL PARK SERVICE
IPM Information Package

WEEDS OF DEVELOPED AND HISTORIC SITES

Final Report

30 August 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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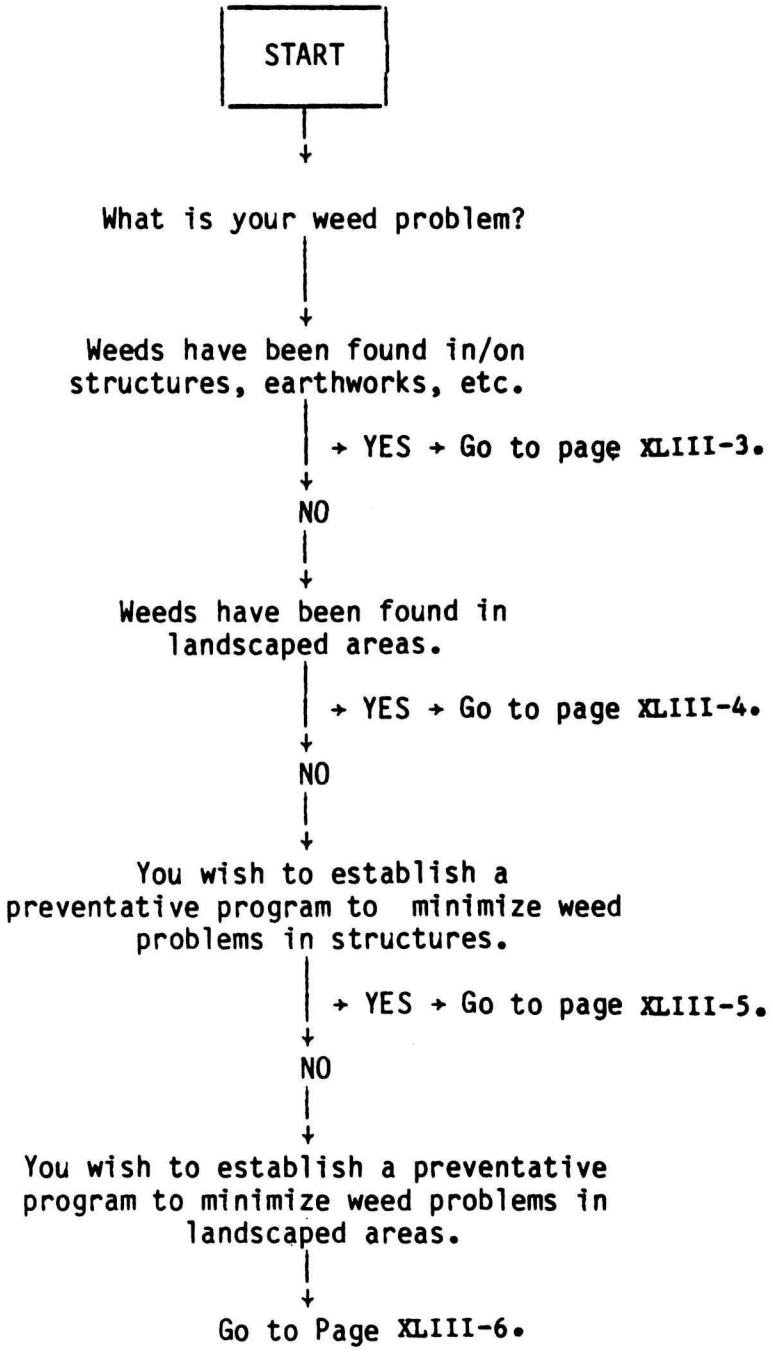
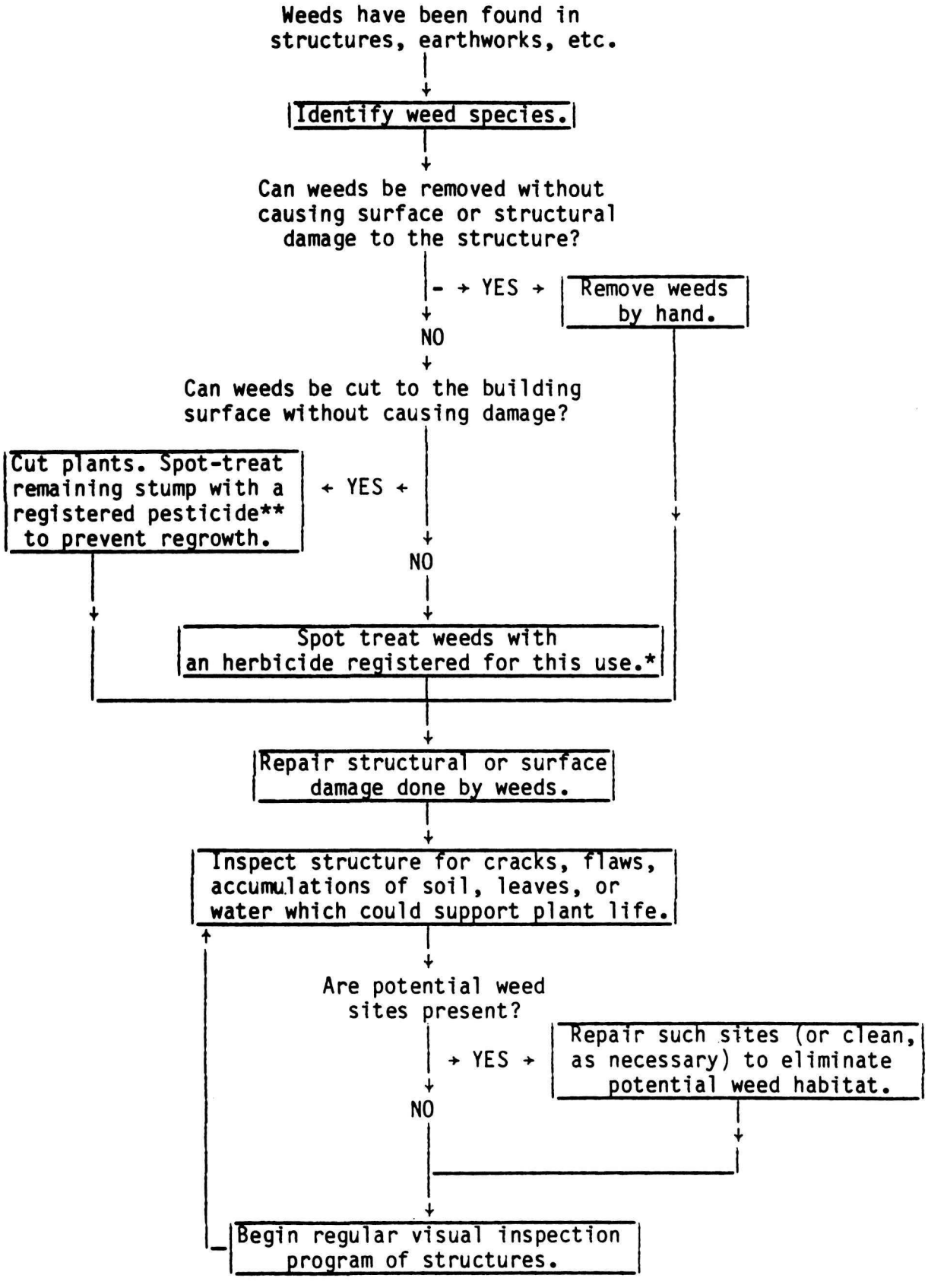
I. WEED IPM DECISION TREE

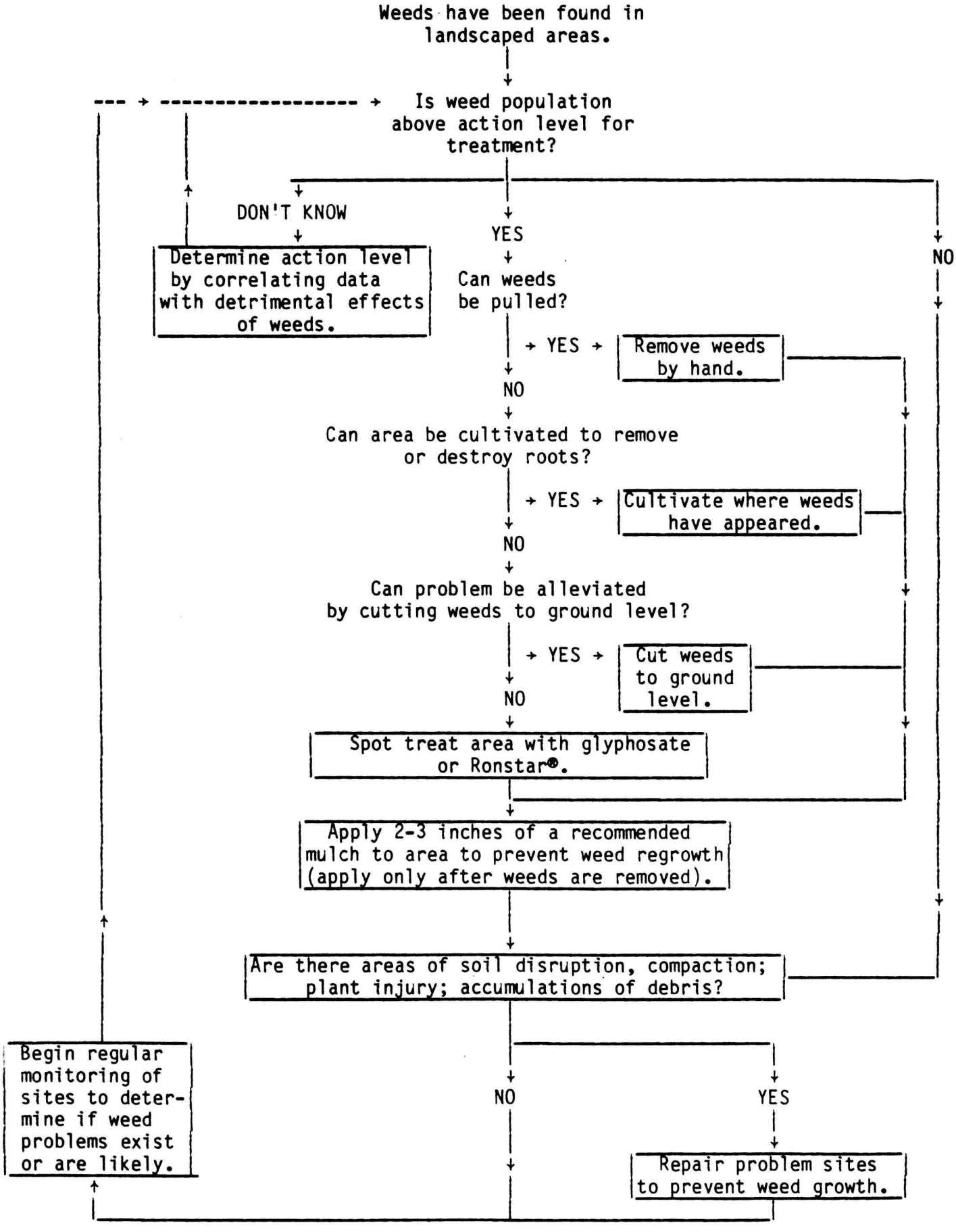
These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to EPA label instructions and be approved on an annual basis by the Director, NPS.

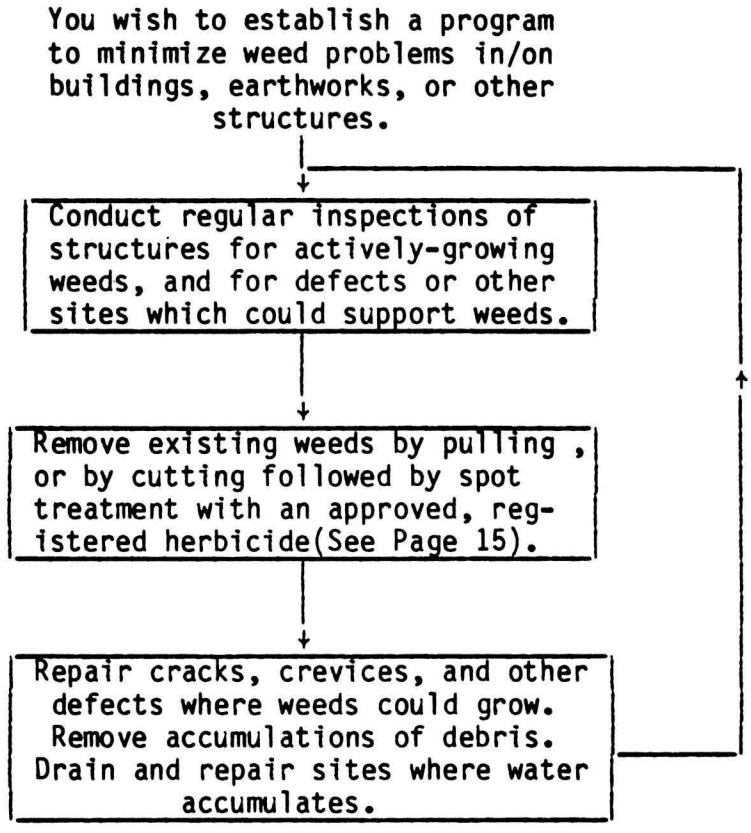


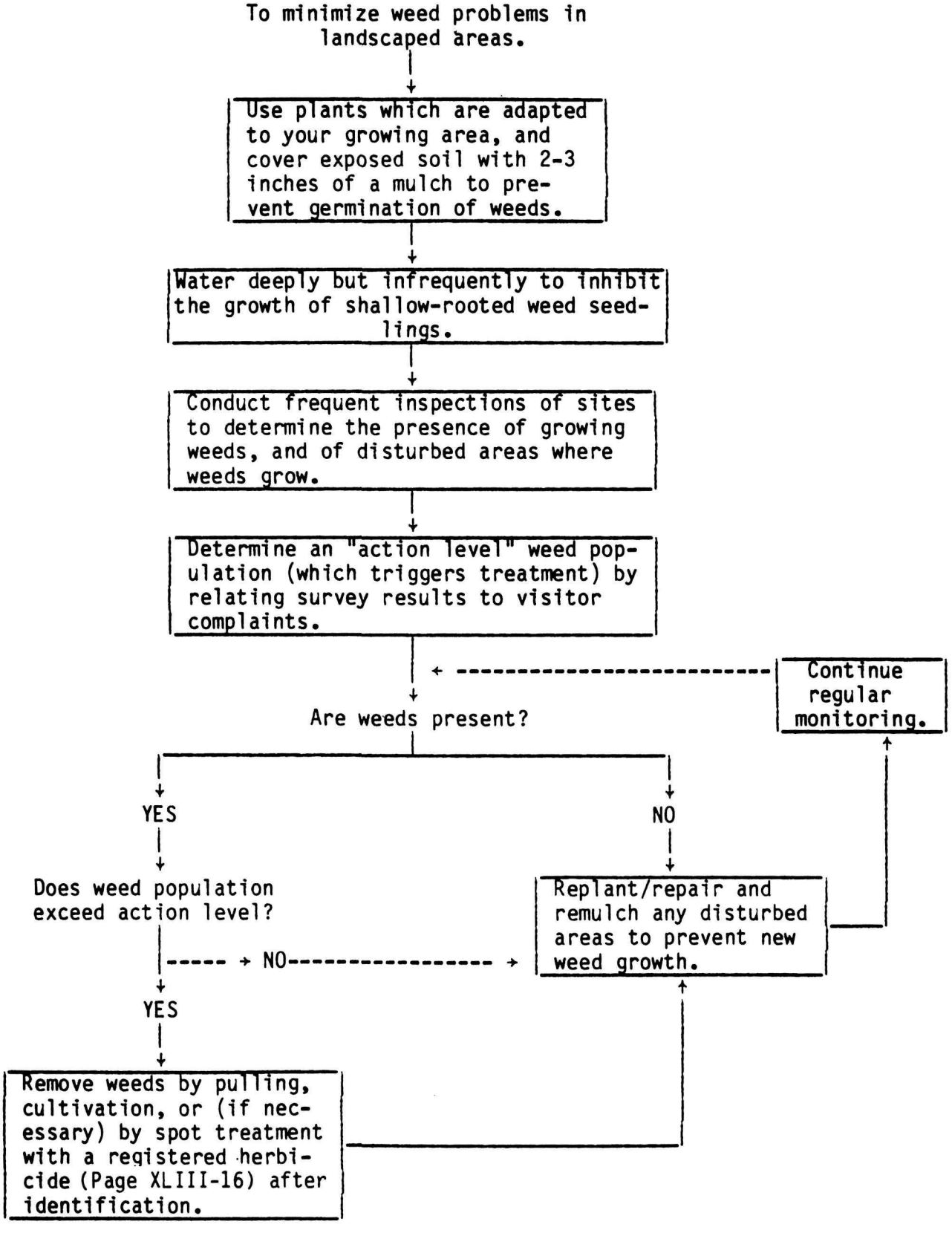


*Use glyphosate or ammonium sulfamate (Page XLIII-16).

**Use ammonium sulfamate (Page XLIII-16).


Weeds have been found in landscaped areas.
Is weed population above action level for treatment?
DON'T KNOW
YES
NO
Determine action level by correlating data with detrimental effects of weeds.
Can weeds be pulled?
YES
Remove weeds by hand.
NO
Can area be cultivated to remove or destroy roots?
YES
Cultivate where weeds have appeared.
NO
Can problem be alleviated by cutting weeds to ground level?
YES
Cut weeds to ground level.
NO
Spot treat area with glyphosate or Ronstar®.
Apply 2-3 inches of a recommended mulch to area to prevent weed regrowth (apply only after weeds are removed).
Are there areas of soil disruption, compaction; plant injury; accumulations of debris?
NO
YES
Repair problem sites to prevent weed growth.
Begin regular monitoring of sites to determine if weed problems exist or are likely.


You wish to establish a program to minimize weed problems in/on buildings, earthworks, or other structures.
Conduct regular inspections of structures for actively-growing weeds, and for defects or other sites which could support weeds.
Remove existing weeds by pulling, or by cutting followed by spot treatment with an approved, registered herbicide(See Page 15).
Repair cracks, crevices, and other defects where weeds could grow. Remove accumulations of debris. Drain and repair sites where water accumulates.


To minimize weed problems in landscaped areas.
Use plants which are adapted to your growing area, and cover exposed soil with 2-3 inches of a mulch to prevent germination of weeds.
Water deeply but infrequently to inhibit the growth of shallow-rooted weed seedlings.
Conduct frequent inspections of sites to determine the presence of growing weeds, and of disturbed areas where weeds grow.
Determine an "action level" weed population (which triggers treatment) by relating survey results to visitor complaints.
Are weeds present?
Continue regular monitoring.
YES
NO
Does weed population exceed action level?
NO
Replant/repair and remulch any disturbed areas to prevent new weed growth.
YES
Remove weeds by pulling, cultivation, or (if necessary) by spot treatment with a registered herbicide (Page XLIII-16) after identification.

II. WEED BIOLOGY AND ECOLOGY

1. Species Described:

Weeds are generally described as any plants growing where they are not wanted. Nearly any plant species can be considered a weed depending on its location; the description of each potential weed species is beyond the scope of this document. We suggest that you contact the United States Dept. of Agriculture Cooperative Extension Service in your state for information on the most important weeds in your region. A list of useful pictorial weed guides is included in the Bibliography section of this report.

2. Geographic Distribution:

As defined above, weeds are found wherever humans interact with an environment which will support plant growth.

3. Habitat:

Two habitats will be considered in this report; landscaped areas (where natural vegetation has been replaced or augmented with other plants, usually for aesthetic purposes), and buildings. Weeds growing in landscaped areas are found where soil has been exposed or disturbed by traffic or planting activities; where the desired plants are weakened by adverse environmental conditions, diseases, or pests to the extent that they cannot compete for nutrients, water, or light with "weed" species; where the desired plantings are not as well adapted to their environment as are native or exotic "weed" species; and where the growth of the desired plants modifies their local environment so that natural ecologic succession to "weed" species can occur (in the absence of control).

Buildings, ruins and other artificial sites can be considered disturbed environments, which (in the absence of control measures) over time will become populated by pioneer plant species, and which will undergo succession to a plant community characteristic of the region in which the site is located. As in normal succession, pioneer species (e.g., mosses, some annual herbs) can become established anywhere that a suitable substrate and water source are found. Gutters; cracks in roofs, walls and foundations; chinks in masonry or stones; gravel roofs; and ledges may accumulate mosses and lichens. Where dust, soil, or other debris accumulates in crevices, recesses, and depressions, higher plants can root. Generally, these are a random assortment of adapted species from the local area plus a few rock-adapted species.

In soil pockets or deep cracks and crevices, woody plants can take root.

4. Hosts:

Most weed plants (including flowering plants, ferns and their relatives, mosses, and lichens) grow on soil or rock, thus do not have hosts per se. Parasitic plants make up a very specialized group, the description of which is beyond the scope of this document.

5. Life Cycles:

The life cycles of flowering weeds (the most common types) can be divided into four major groups:

A. Summer annual weeds (e.g., morning glory, ragweed, and crabgrass) grow each spring or summer from seed. They grow, mature, produce seeds, and die in one growing season. Seeds generally overwinter before germinating the following spring.

B. Winter annual weeds (e.g., field pepperweed, shepherds-purse) germinate in late summer or fall from seed, then mature and produce seed the following spring or summer. Seeds of most of these species are dormant during the spring. Some species (e.g., chickweed) can germinate under snow cover, and produce new seed by May or June, allowing two generations per year.

C. Biennial weeds (e.g., wild carrot, bull thistle) may germinate at any time during the growing season. They usually produce a rosette of leaves close to the soil during the first season, then flower (using energy stored during the first season's growth), mature, and die during the next year.

D. Perennial weeds (e.g., dandelion, vines, shrubs, trees) become established by seed or vegetative parts (e.g., roots, tubers, rhizomes). Once established, they live for more than two years, and often for many years.

Lower plants will generally fall into one of the above general life cycle types, with reproduction by seed, spore, or vegetative plant part. Multiple yearly generations may occur in some species.

6. Seasonal Abundance:

Perennials, biennials, and annuals may all exhibit foliar growth during the spring, summer, and fall. Certain perennials, biennials, and winter annuals will retain their foliage through the winter. The relative proportions of these types of weeds varies according to geographic, ecologic, and climatic characteristics of the region of concern.

7. Response to Environmental Factors:

Critical environmental factors for plants (including weeds) include temperature, light intensity and spectrum, atmospheric moisture level, soil moisture, substrate composition, substrate texture, types and availability of nutrients, competition from other plants, and antagonism by other organisms. Each plant species will grow best under a specific level (or range) of each of these factors. The range of acceptable environments among those plant species in any given region is always great enough to guarantee that any site which becomes able to support plant life will eventually be colonized by species able to make use of the conditions available.

Certain nonchemical control methods are designed to limit or prevent weed growth by limiting one or more of these critical factors (e.g., mulching and cultivation, which keep light from weed seeds, preventing their germination). These methods are described in Section III.3. of this report.

8. Impact of Weeds:

8.1 Direct Impact

The direct impacts of weeds on landscaped areas include:

A. Competition with and replacement of desired plants by better-adapted weed species.

B. Creation of unsightly patches of growth and/or dead areas when annuals overgrow desired plants and then die (e.g., annual dropseed grass).

C. Toxicity to humans and animals. Many common weeds are poisonous if consumed (e.g. Johnsongrass, pokeweed), or may cause inflammation when touched (e.g., stinging nettle, poison ivy, oak, and sumac), or may cause allergic reactions (e.g., common ragweed and many grasses).

D. Creation of nuisance conditions causing visitor discomfort (e.g., covering of trails or signposts by fast-growing species, or visitor injury due to spines or thorns of many weed species).

E. Necessity for increased expenditures for landscape maintenance to control weed population.

Direct impacts of weeds growing on/in buildings and other structures include:

A. Structural damage caused by plant growth between boards or bricks, leading to separation of walls or other parts.

B. Destruction of earthworks due to root penetration;

C. Obstruction of structures and historic landscapes and vistas due to overgrowth of surfaces by weeds.

D. Staining of building surface or facing materials.

8.2 Indirect Impact:

Weeds can serve as secondary hosts for microbes and insects which may damage desirable plantings. Weedy areas may also become habitats for rodents and arthropods (e.g., rats, ticks, mites, mosquitoes, biting flies) which attack humans and domestic animals, and/or carry diseases affecting humans and other animals.

9. Natural Enemies:

Weed species are subject to attack by many natural enemies, including herbivorous mammals, reptiles, birds, and insects; disease organisms such as fungi, bacteria, nematodes, viruses, and spiroplasmas; and allelopathic plants (which produce chemicals inhibitory or toxic to the weed). Plant species better adapted than the weed to the particular growing site may out-compete and replace a weed species. Certain antagonistic organisms have been adapted for biocontrol of specific weeds in aquatic and agricultural situations (e.g., biocontrol of water-hyacinth by exotic insects and a fungus). However, no adapted biocontrol agents are currently available commercially for control of weeds on structures, or in ornamentals or turf.

III. WEED MANAGEMENT

1. Population Monitoring Techniques:

Integrated weed management is not yet a highly-developed discipline. To date, the best technique for monitoring weed populations is visual observation:

A. On structures, earthworks - Conduct regular (weekly) inspections of all structures for the presence of weed growth, extent of damage that can be correlated with the presence of plant growth, and structural defects that could be colonized by weeds.

B. In landscaped areas - Conduct regular (weekly) inspections throughout the growing season for the presence of actively growing weeds, and areas where the plantings have been disturbed in such a way that the sites could support new weed growth. Such disturbances include:

- o Cultivation (which can expose previously buried weed seeds to light);
- o Soil exposure due to visitor traffic or mulch removal;
- o Flooding;
- o Drought;
- o Soil compaction (due to pedestrian or vehicular traffic);
- o Infestations of plant diseases or insects;
- o Accumulations of leaves or other debris;
- o "Dog Blight", caused by animal urine.

Additional inspections during the winter (or fallow periods) should be made for signs of new weed growth, or of other damage to plantings (which could make the site favorable for weed growth).

2. Threshold/ Action Population Levels:

A. On structures - For the majority of historic or other structures, an appropriate threshold level (above which some damage can be expected) is zero weeds. On ruins and earthworks, levels should be set to prevent structural damage, aesthetic interference and visitor complaints.

B. In landscaped areas - It is extremely difficult to set specific threshold population levels for weeds in landscaped sites, since the problems caused by weeds are largely aesthetic, rather than medical or economic. Each park manager should establish threshold and action levels for his/her own area by correlating records of weed populations with visitor complaints (of visual nuisance, traffic obstruction, and/or injury).

3. Management Alternatives - Nonchemical:

A. On structures

1. Mechanical methods

a. Weed removal - Weeds should be removed by hand where possible, and where their removal will not result in further damage to the infested structure (e.g., if pieces of mortar are pulled out with the weed, do not pull any more!). Trees or shrubs growing on ruins or earthworks should not be removed until it can be determined that their removal will not cause more damage than would their continued growth. If weeds are removed, stabilization procedures should begin after removal.

b. Cutting - Weeds which cannot be completely removed from the affected structure can be cut as much as possible. However, frequent monitoring for regrowth will be required. Vines should be kept away from rain gutters, window or door sashes, or other exposed wood.

c. Maintenance of buildings - Frequent building inspection should be conducted to discover cracks, crevices, accumulations of debris or water, and other sites which could support weed growth. When found, such areas should be cleaned and/or repaired, to prevent future weed growth.

B. In landscaped areas

1. Mechanical methods

a. Weed removal - Established weeds can be removed by hand.

b. Cutting - Weeds can be cut to ground level, but will generally regrow. Repeated cutting may weaken some weeds by draining nutrient reserves from their roots. Cutting will keep annual weeds from producing new seeds if it is performed before flowering.

c. Cultivation - Cultivation of soil around landscape plantings can bury weed seeds (many of which need light to germinate), break-up and smother weed seedlings, and weaken perennial weeds by removal of foliage and roots.

2. Physical methods

a. Heat treatment - Since weeds (and other plants) are killed by exposure to temperatures above 113-131°F, fire has been used (i.e., as flame throwers) to control weeds along rights of way. This control method is probably not suited for use at most park sites.

Weed seeds in soil can be killed (along with other microbes) by treating the soil with aerated steam (Aldrich et al., 1972) before it is used for plantings. While this method is effective for conservatory and other small plantings, it is usually too expensive for large-scale outdoor use.

3. Cultural methods

a. Flooding - This method has certain uses in agricultural systems, but is not applicable to most park situations.

b. Mulching - Among the other advantages of the use of mulches (e.g., thermal insulation, increased water-holding capacity, retardation of evaporation of soil moisture), these materials will eliminate or retard

weeds by eliminating the light that weed seeds require for germination. Mulches should be applied to planted areas in mid-spring when the soil is warm enough for active root growth.

Mulches should be at least 2-3 inches deep over the treated area, but should not contact stems or trunks of desirable plants (to keep the plants free of wet spots where disease organisms can grow). Certain mulches may contain weed seeds (e.g., hay, straw, and strawy manures) and should be avoided. Some recommended mulches are:

- Sphagnum peat moss - Ideal for mulching acid-loving plants such as evergreens. Good color, and remains effective 1-2 years.
- Bark (shredded) - Good texture, long effective life. Excellent for all plants.
- Crushed stone - Available in various colors. Long lasting. Some types (e.g., limestone) may alter soil pH levels.
- Black polyethylene - Unsightly. Must be held in place to prevent wind from carrying the material away.
- Crushed corncobs - Additional fertilization of plantings may be required if this mulch is used.
- Buckwheat hulls - Long lasting, good color; may blow away in windy areas.
- Dark, rotted sawdust - Preferable to fresh sawdust; some nitrogen must be added to soil if this is used.
- Fiberglass mats - Will not rot, corrode, or burn; long lasting.
- Other materials - Spent hops, lawn clippings, leaves (especially oak, since they do not pack down too closely), cocoa bean hulls, leaf mold, and paper pulp have all been used for mulching.

- o Living mulches - Certain ground cover plants are effective in landscaped areas as living mulches which shade the surface soil, and aid in soil water retention. These include Euonymus varieties, Vinca, honeysuckle, Ajuga, Phlox subulata, bedding petunias, annual alyssum, Sedum varieties, and native ferns.

Consult your local USDA Cooperative Extension Service agent for details on preferred materials for your region.

4. Biological control - No biological control agents have been approved by the U.S. Environmental Protection Agency for use in landscape or structural situations. However, the use of nonchemical control methods (or chemicals with a limited host range) for control of insects and other pests will permit naturally-occurring weed controls to operate at maximum effectiveness.

4. Management Alternatives - Chemical:

Many herbicides are currently registered for the control of weeds in ornamental plantings, and for structural applications. The choice of the chemical to be used on a particular site should follow the key shown here:

A. Weeds near water..... Rodeo® or Ammate®.

B. Weeds not near water.

1. Selective herbicides.
   - a. For grasses.
     - i. For annual grasses.
       - aa. In grass.....siduron.
       - bb. In broadleafs..... dalapon or oryzalin.
     - ii. For perennial grasses.
       - aa. In grass..... triazines.
       - bb. In broadleafs..... dalapon.
   - b. For broadleafs.
     - aa. In grass..... MCPP, 2,4-D.
     - bb. In broadleafs..... Spot treat with Round-up®.

2. Nonselective herbicides.....NEXT PAGE.

2. Nonselective herbicides.

a. For annuals.....	Mechanical treatment is recommended.
b. For perennials.	
i. Herbaceous spp.....	Roundup or Ammate or simazine(pre-emergence).
ii. Woody spp.....	Roundup or Ammate.

Contact your NPS IPM Coordinator for additional information concerning which, if any, of these products is best for your particular weed management requirements.

5. Summary of Management Recommendations:

Effective weed control in landscaped ares and in/on park structures involves the following procedures:

A. Regular monitoring of all sites for weed growth, and for signs of disturbance (e.g., building cracks, compacted or exposed soil, dead plants, and accumulations of debris) which could promote or support weed growth.

B. Maintenance of sites so that such disturbances are prevented or repaired. This includes repair of building defects, mulching of landscaped areas, removal of accumulated debris, and the use of plantings which are well-adapted to their site, so that they will be less likely to be overgrown by weed species.

C. Removal of weeds, when found. Mechanical procedures such as pulling or cultivation will often eliminate the problem. Spot treatment with a registered, approved herbicide may be necessary to destroy certain annual or perennial weeds.

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Consult your local USDA Cooperative Extension Service agent, State University, or regional IPM coordinator for weed identification guides and services specific for your area.

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NATIONAL PARK SERVICE
IPM Information Package

WEEDS OF PATHWAYS AND ROADWAYS

Final Report

18 April 1985

Submitted To:

Mr. Gary H. Johnston
National Park Service, USDI
Washington, D.C. 20240

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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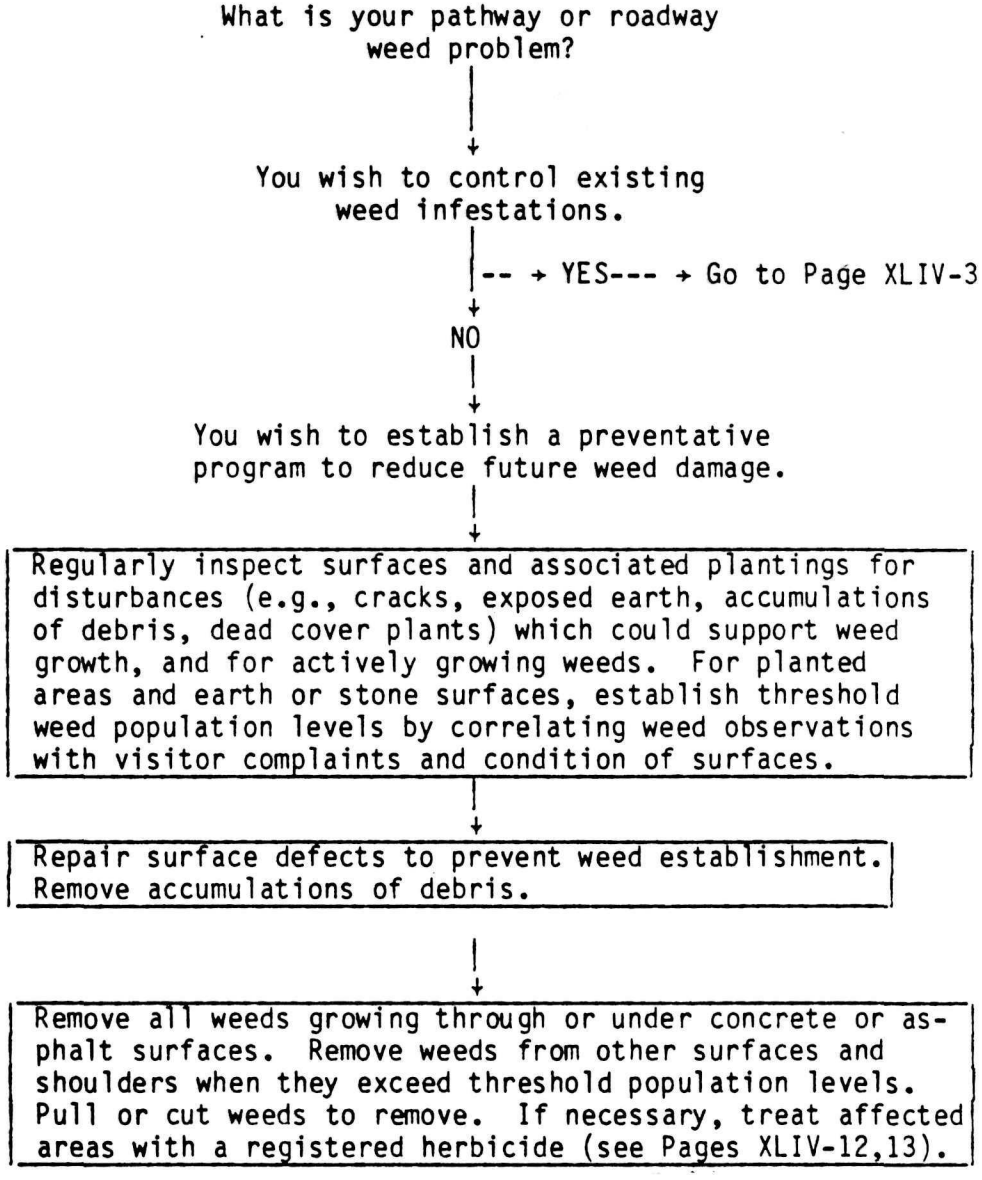
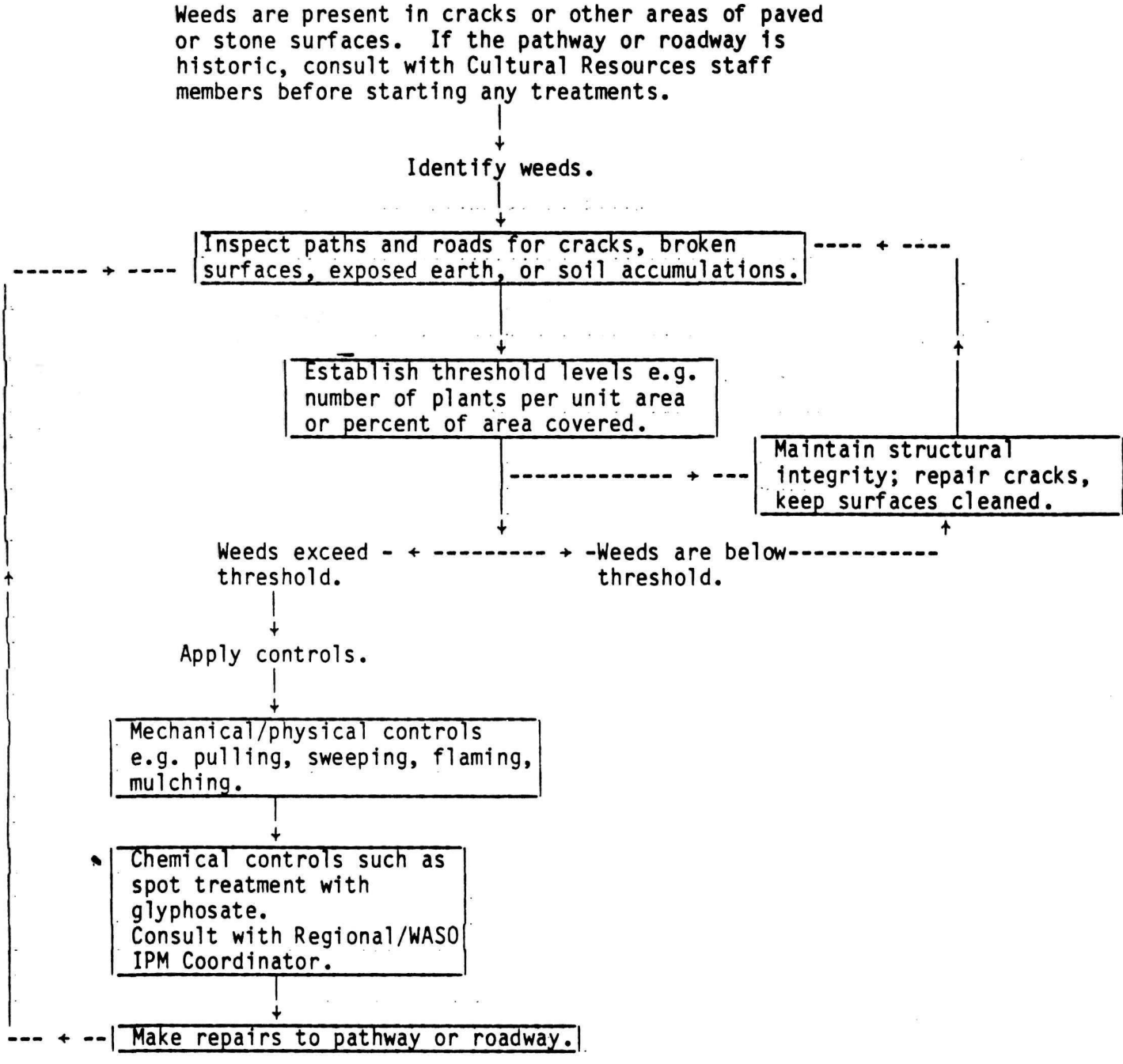
I. PATHWAY AND ROADWAY WEEDS IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.




Weeds are present in cracks or other areas of paved or stone surfaces. If the pathway or roadway is historic, consult with Cultural Resources staff members before starting any treatments.
Identify weeds.
Inspect paths and roads for cracks, broken surfaces, exposed earth, or soil accumulations.
Establish threshold levels e.g. number of plants per unit area or percent of area covered.
Maintain structural integrity; repair cracks, keep surfaces cleaned.
Weeds exceed threshold.
Weeds are below threshold.
Apply controls.
Mechanical/physical controls e.g. pulling, sweeping, flaming, mulching.
Chemical controls such as spot treatment with glyphosate. Consult with Regional/WASO IPM Coordinator.
Make repairs to pathway or roadway.

II. PATHWAY AND ROADWAY WEEDS BIOLOGY AND ECOLOGY

1. Weeds Described:

Weeds are generally described as any plants growing where they are not wanted. Any plant species may be considered a weed if it grows through the surface or along the edge of a pathway or roadway in a manner that impedes traffic; causes or promotes injuries to visitors; obscures the view of scenic or historic structures or other points of interest; produces or accumulates debris; or requires frequent mowing or other care to avoid becoming unsightly.

While tall or woody plants are most likely to constitute vision-blocking safety hazards, shorter herbaceous plants (grasses and broadleaves) may contribute to any of the problems noted above. The description of every potential pathway/roadway weed species is beyond the scope of this document. We suggest that you contact the United States Department of Agriculture Cooperative Extension Service in your state for information on the most important weeds in your region. A list of useful pictorial weed guides is included in the Bibliography section of this report.

2. Geographic Distribution:

Weeds may be found wherever pathways or roads are constructed.

3. Habitat:

A pathway is any walk, trail, or way constructed for foot traffic. A path may be as simple as a track devegetated by frequent use (e.g., a forest trail), or may consist of graded and compressed earth, tile, brick, cobblestone, concrete, asphalt, wood, sand, etc., or one or more layers of crushed stone, other inorganic or organic mulch (e.g., bark chips) built over or in the natural ground surface.

A roadway is an artificial environment consisting of the road itself, within a zone (shoulders) which separates the road from the surrounding natural environment. The road may range in construction from a complex, multilayered structure topped with concrete or asphalt, through simpler forms (e.g., a single layer of asphalt or crushed stone over packed earth), to basic forms (e.g., compressed earth). The shoulders may consist of graded earth, crushed stone over earth, or soil planted in a ground cover species (e.g., grasses, crown vetch). Ground covers and/or angled grading may be used where erosion would be a problem.

Road surfaces and pathways can be considered disturbed environments, which (in the absence of control measures) will become populated over time by pioneer plant species which will undergo succession to a plant community characteristic of the region in which the path is located. Pioneer species (e.g., certain annual herbs) can become established anywhere that a suitable substrate and water source are found.

Cracks in concrete or asphalt surfaces can accumulate debris and soil in which weeds can grow. The high light intensity, frequent disturbance, and exposed soil or dirt, mulch, or stone paths (especially where regular maintenance is not performed) can promote weed seed accumulation, germination, and establishment.

Weeds can become established in planted shoulders where the soil has been exposed or disturbed by heavy traffic or other activities; where the desired plants are weakened by adverse environmental conditions, diseases, or pests to the extent that they cannot compete for nutrients, water, or light with "weed" species; where the desired plantings are not as well adapted to their environment as are native or exotic "weed" species; and where the growth of the desired plants modifies the local environment so that natural ecologic succession to "weed" species can occur (in the absence of control).

4. Hosts: Not applicable.

5. Life Cycles: The life cycles of pathway and roadway weed plants can be grouped into the following major types:

A. Summer annual weeds (e.g., morning glory, crabgrass) sprout each spring or summer from seed. They grow, mature, produce seeds, and die in one growing season. Seeds generally overwinter before germinating the following spring. The majority of annual weeds are of this type.

B. Winter annual weeds (e.g., field pepperweed, annual bluegrass) germinate in the fall or late winter from seed, mature and produce seed during the following spring, and die in early summer. Seeds of most of these species are dormant during the spring.

C. Indeterminate annual weeds (e.g., common chickweed) may germinate and grow during any part of the year.

D. Biennial weeds (e.g., wild carrot, bull thistle, sweet clover) may germinate at any time during the growing season. They usually produce a radial cluster (rosette) of leaves lying close to the soil during the first season. During the second year, they produce flower stalks (using energy stored during the first season's growth), produce seeds, and die.

E. Perennial weeds live for three or more years. Some species may not flower the first year, and others may produce mostly nonviable seeds. While many perennials (e.g., curly dock, dandelion, common milkweed) spread primarily by producing seeds, many others (e.g., field bindweed, silverleaf nightshade) spread both by seed and vegetatively (asexually). Vegetative spread may be by rhizomes, stolons, tubers, or rooting of stem nodes that touch soil. Still other species (e.g., purple nutsedge) spread mainly by asexual means.

6. Seasonal Abundance:

The seasonal abundance of weeds is related to their specific life cycles. Summer annuals grow from spring until fall, when they are killed by low temperatures. Winter annuals are present from fall to late spring, so will not usually be found during the summer. Biennials grow during the spring, summer, and fall of their first year, survive over the following winter, and flower during the next growing season; therefore, some biennial life stages are likely to be present at any time of the year. Perennials grow during each growing season. Their aboveground structures may die over the winter, or may remain viable but dormant.

7. Responses to Environmental Factors:

Plants that are able to establish and survive on disturbed areas possess a great tolerance for a broad range of environmental conditions including soil disturbance and partial defoliation (Anderson, 1983). Their seeds may remain viable in the soil for several years until conditions favor germination. The seeds of many herbaceous weeds require high light levels and exposed mineral soil for germination. Weed species usually grow more vigorously than the plants they displace, and usually can grow under a wider range of conditions than desired species. Many weed species possess efficient methods of seed dispersal (e.g., wind dissemination of light, winged or hairy seeds), and/or other means of rapid spread (e.g., rhizomes, runners, tubers, bulbs). The particular group of species that an area will support will vary with the climate of the area, the nutrient levels in the soil, and the availability of light and moisture.

8. Impact of Pathway and Roadway Weeds:

8.1 Direct Impact: The direct impacts of weeds on pathway and roadway areas include:

A. Damage to paved surfaces due to the growth of plants (e.g., expansion of roots under the surface, leading to cracking; or growth of seedlings through existing surface cracks).

B. Obstruction of unpaved paths by weeds growing in or through the path surface or on exposed soil.

C. Blockage of user and/or driver vision (of obstructions, and of scenic or historic scenery or structures) due to the growth of tall herbs, shrubs, or trees.

D. Creation of driving hazards due to collecton of leaves, soil, and debris in or under weeds growing on the road surface or shoulders.

E. Interference with proper drainage of water from road surfaces, due to overgrowth of weeds adjacent to roads.

F. Hiding of fences or directional signs from view, due to the growth of tall weeds.

G. Competition with and replacement of desired plants on shoulders by better-adapted weed species.

H. Creation of nuisance conditions causing visitor discomfort (e.g., visitor injury due to spines or thorns of many weed species).

I. Creation of unsightly patches of growth and/or dead areas when annuals overgrow desired plants and then die (e.g., annual bluegrass). Replacement of ground cover plants by such species could lead to increased soil erosion due to lost cover.

J. Necessity for increased expenditures for road and pathway maintenance to control weed populations.

8.2 Indirect Impact: Weeds can serve as secondary hosts for microbes and insects which may damage desirable plantings. Weedy areas may also become habitats for rodents and arthropods (e.g., ticks, mites, mosquitoes, biting flies) which attack humans and domestic animals, and/or carry diseases affecting humans and other animals.

The presence of weeds near a roadway may attract wildlife or other animals, presenting a hazard to visitors and to their vehicles, as well as to the animals themselves.

9. Natural Enemies:

Weed species are subject to attack by many natural enemies, including herbivorous mammals, reptiles, birds, and insects; disease organisms such as fungi, bacteria, nematodes, viruses, and spiroplasmas; and allelopathic plants (which produce chemicals inhibitory or toxic to the weed). Plant species better adapted than the weed to the particular growing site may out-compete and replace a weed species. Although biocontrol agents for control of weeds in pathways and roadways have received limited attention, some successful programs have included the following:

1. Penned goats have been used successfully in California (Gary Johnston, personal communication).

2. Thistles (Carduus and Cirsium spp.) have been controlled using imported herbivorous insects. See IPM Information Package XXXVI for details.

III. PATHWAY AND ROADWAY WEED MANAGEMENT

1. Population Monitoring Techniques:

Integrated weed management is not yet a highly-developed discipline. To date, the best technique for monitoring weed populations is visual observation. To monitor weeds in some situations, the following procedure is recommeded:

1. Define the square footage of the area.

2. Walk the area and list all the weeds present.

3. Set up a monitoring protocol using a square meter or square foot grid or loop.

4. Randomly toss the grid or loop a desired number of times in the defined area. Count the actual number of weeds in each toss of the loop/grid.

5. Repeat twice or more per growing season.

Conduct regular (monthly) inspections of all pathways and roads for the presence of weed growth, and for cracks in pavement surfaces or other disturbances that could be colonized by weeds. Such disturbances include:

Soil exposure due to heavy visitor or vehicular traffic, flood, drought, cultivation, or mowing.

Loss of cover vegetation due to soil compaction (due to pedestrian or vehicular traffic), infestations of plant diseases or insects, accumulations of leaves or other debris, road salt toxicity, erosion, or adverse weather conditions.

Inspections should be made during the local growing season for evidence of active weed growth. Additional inspections during the winter should be made for signs of damage to paved surfaces, damage to border strip plantings (which could make the site favorable for weed growth).

2. Threshold/ Action Population Levels:

A. On concrete or asphalt surfaces, an appropriate threshold level (above which some damage can be expected) is zero weeds. On crushed stone, dirt, and mulched surfaces, levels should be set to prevent structural damage to the surface, aesthetic interference, and visitor complaints.

If historic materials are part of a road or pathway, consult with Cultural Resources Staff members to

determine injury levels and appropriate treatments.

In landscaped or cover-planted areas, it is extremely difficult to set specific threshold population levels, since the problems caused by weeds are largely aesthetic, rather than medical or economic. Hence, threshold levels will vary from site to site; initial levels may be arbitrary until park personnel have worked with the system for some time. Careful record keeping in conjunction with monitoring will, over a period of several seasons, be useful in determining threshold levels and problem areas.

3. Management Alternatives-Nonchemical:

1. Mechanical methods - Timing of treatments should coincide with the period of greatest susceptibility (ie., flaming in dry weather, cutting when weeds are young, etc.) in order to achieve maximum damage to weeds.

a. Weed removal - Established weeds can be removed by hand. Some weeds with long tap roots cannot be totally removed by pulling; remaining roots or underground stems or crowns may resprout. Removal of woody plants with extensive root systems may be destructive to paved surfaces. Use of a street sweeper machine for large flat areas or use of stiff wire brushes to clean out organic material will reduce or prevent seed germination.

b. Cutting - Weeds which cannot easily be removed from the path or road, or which are not directly damaging the surface (e.g., weeds emerging from the bases of railings or fenceposts) can be cut as low as possible. However, frequent monitoring for regrowth will be required. In addition, such weeds may grow under the surface, damaging it by expansion, if cutting is not frequent enough to weaken the plants.

c. Flaming - Above-ground plant parts can be heated to raise internal temperatures to lethal levels using a propane torch or other source of heat. The flame should be passed quickly over the plant, and should not be held long enough to blacken or char the plant. The plant soon dies without leaving blackened or scorched areas. Roots will not be killed by this technique, and may resprout. Plants may be difficult to flame in wet weather, and during active growth (due to high water content).

d. Mulching - Application of a layer of crushed stones (at least 3" deep) to unpaved surfaces and unplanted shoulders will prevent the germination and establishment of most weeds, and provide a useful traffic-bearing surface. Geotextiles (e.g., black plastic mulches) along the edges of pathways or under some materials such as brick or wood chips, prevent germination and growth of weeds.

e. Maintenance of roads and pathways - Regular inspection should be conducted to discover cracks in paved surfaces, exposed soil, accumulations of debris or water, and other sites which could support weed growth. When found, such areas should be cleaned and/or repaired, to prevent future weed growth.

2. Cultural methods - Cover management practices which increase the health, density, and general vigor of the desired plants will discourage weeds through competition. Such methods include:

a. Use of plants which are adapted for the specific planting area (i.e., climate, light intensity, soil type) and type of use (e.g., low maintenance, rapid spread) will promote the best possible cover development.

b. Maintenance of optimum soil conditions for cover species through adequate feeding based on soil testing.

c. Mulching - Among the other advantages of the use of mulches (e.g., thermal insulation, increased water-holding capacity, retardation of evaporation of soil moisture), these materials will eliminate or retard weeds by eliminating the light that weed seeds require for germination. Mulches should be applied to planted areas in mid-spring when the soil is warm enough for active root growth.

Mulches should be at least 2-3 inches deep over the treated area, but should not contact stems or trunks of desirable plants (to keep the plants free of wet spots where disease organisms can grow). Certain mulches may contain weed seeds (e.g., hay, straw, and strawy manures) and should be avoided. Some recommended mulches are:

i. Bark (shredded) - Good texture, long effective life. Excellent for all plants, and makes a useful path surface.

ii. Crushed stone - Available in various colors. Long lasting. Some types (e.g., limestone) may alter soil pH levels. Good for path surfaces.

iii. Living mulches - Certain ground cover plants are effective in landscaped areas as living mulches which shade the surface soil, and aid in soil water retention. These include Euonymus varieties, Vinca, honeysuckle, Ajuga, Phlox subulata, bedding petunias, annual alyssum, Sedum varieties, and native ferns. Consult your regional IPM Coordinator for details on preferred materials for your region. Certain low covers can withstand light to moderate foot traffic, and can be used as natural path surfaces. Contact your local U.S. Department of Agriculture Extension Agent for varietal recommendations.

iv. Geotextiles - Sheets of black plastic under some path surfaces are highly effective in preventing weed germination and growth, and aid in soil water retention. Black plastic mulches are commercially available in a variety of thicknesses. Care should be taken not to puncture the covering, allowing light to reach the soil and possible sprouting of weed seeds. Geotextiles are not recommended for use under heavily used pathways, or as path surfaces.

3. Biological control - No biological control agents are currently available for use on pathways. However, the use of nonchemical control methods (or chemicals with a limited host range) for control of insects and other pests will permit naturally-occurring weed controls to operate at maximum effectiveness.

4. Management Alternatives - Chemical:

Many herbicides are currently registered for the control of weeds in pathways and associated planted or landscaped areas. The choice of the chemical to be used on a particular site should follow the key shown on the following page. Use of these herbicides require WASO approval on an annual basis for use on park land.

A. Weeds near water.....Rodeo® or Ammate®.

B. Weeds not near water.

1. Selective herbicides.

a. For grasses.

i. For annual grasses.

aa. In grass.....siduron.

bb. In broadleafs...dalapon or oryzalin.

ii. For perennial grasses.

aa. In grass.....triazines.

bb. In broadleafs...dalapon.

b. For broadleafs.

aa. In grass.....MCPP, 2,4-D.

bb. In broadleafs...Spot treat with Round-up®.

2. Nonselective herbicides.

a. For annuals.....Mechanical treatment is recommended.

b. For perennials.

i. Herbaceous spp.....Roundup or Ammate or simazine(pre-emergence).

ii. Woody spp.....Roundup or Ammate.

Contact your regional or WASO IPM Coordinator for additional information concerning which, if any, of these products is best for your particular weed management requirements.

Summary of Management Recommendations:

1. Regular monitoring of all sites for weed growth, and for signs of disturbance (e.g., surface cracks, compacted or exposed soil, dead plants, and accumulations of debris) which could promote or support weed growth.

2. Maintenance of sites so that such disturbances are prevented or repaired. This includes repair of surface defects (cracks, missing mortar), mulching of landscaped areas, removal of accumulated debris, and the use of plantings which are well-adapted to their sites, so that they will be less likely to be overgrown by weed species.

3. Removal of weeds, when found. Mechanical procedures such as pulling, cultivation, or use of street sweepers or stiff brushes to remove weeds at the surface level, will often eliminate the problem. Spot treatments with a registered, approved herbicide may be necessary to destroy certain annual or perennial weeds.

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NATIONAL PARK SERVICE
PEST MANAGEMENT REPORT

YELLOWJACKETS

Final Report

31 July 1984

Submitted To:

William E. Currie
Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

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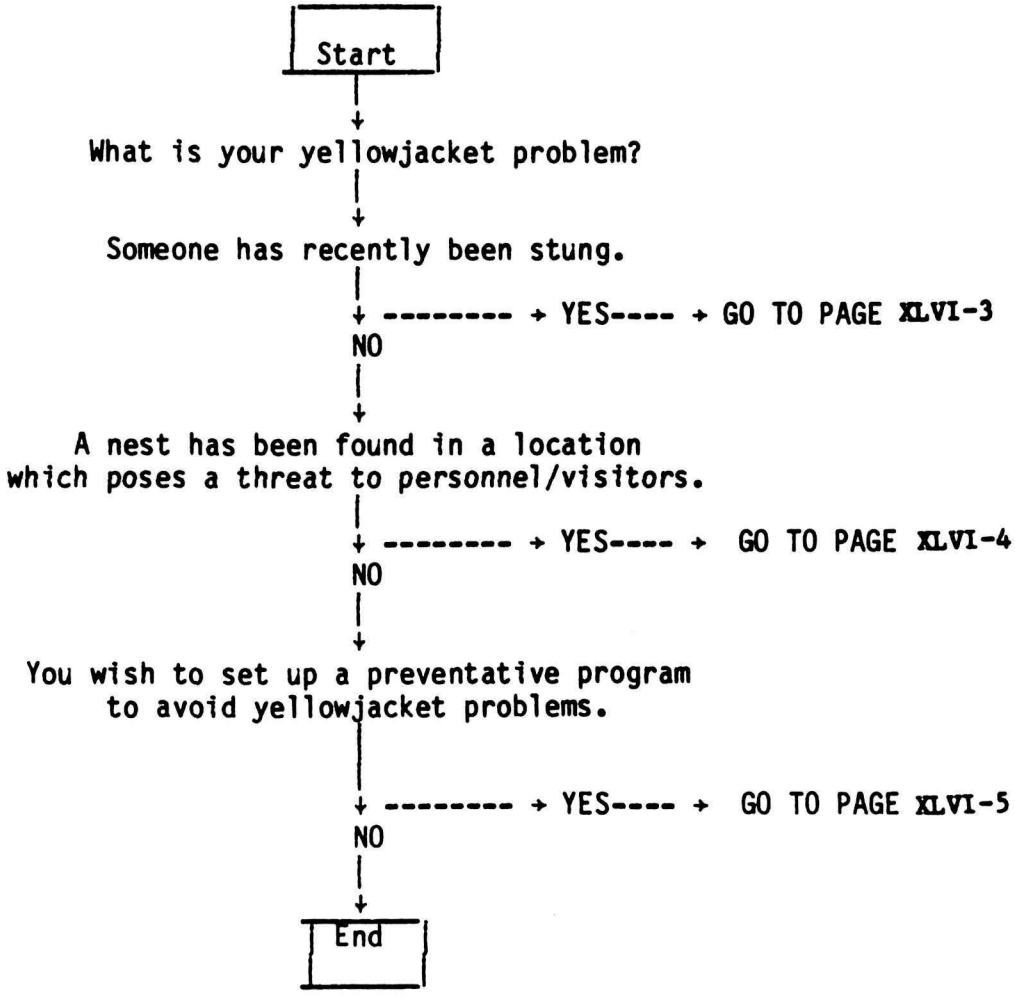
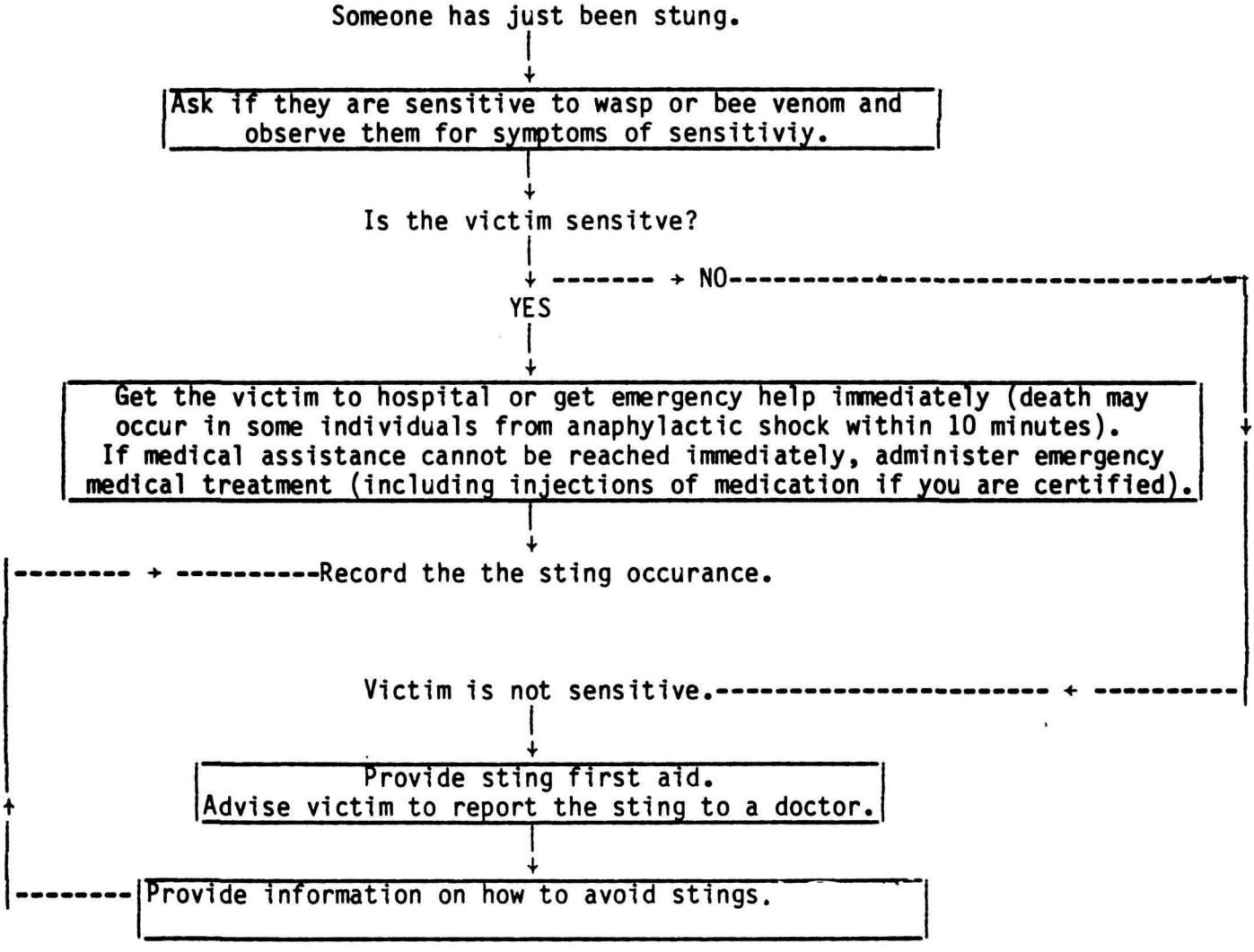
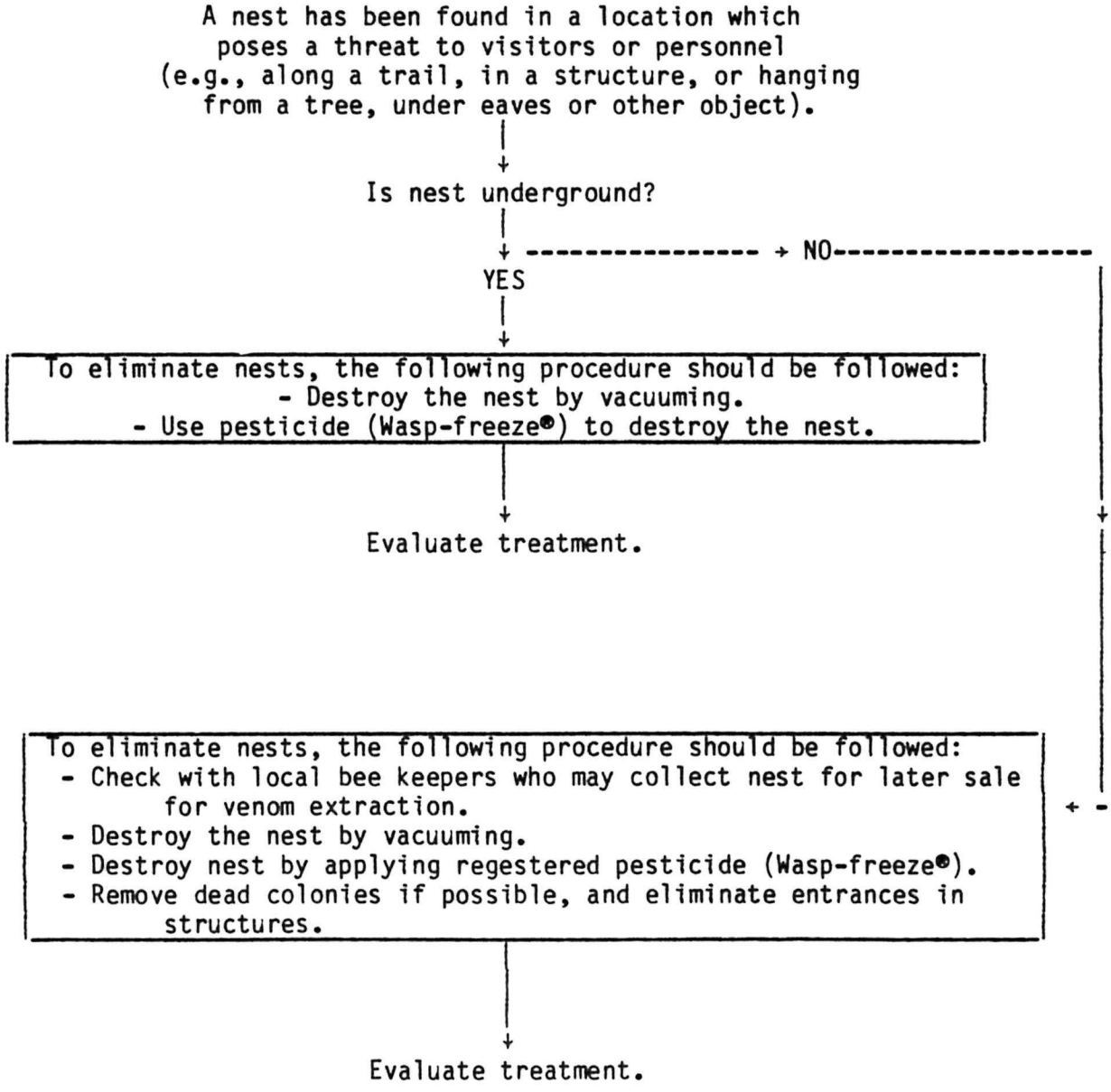
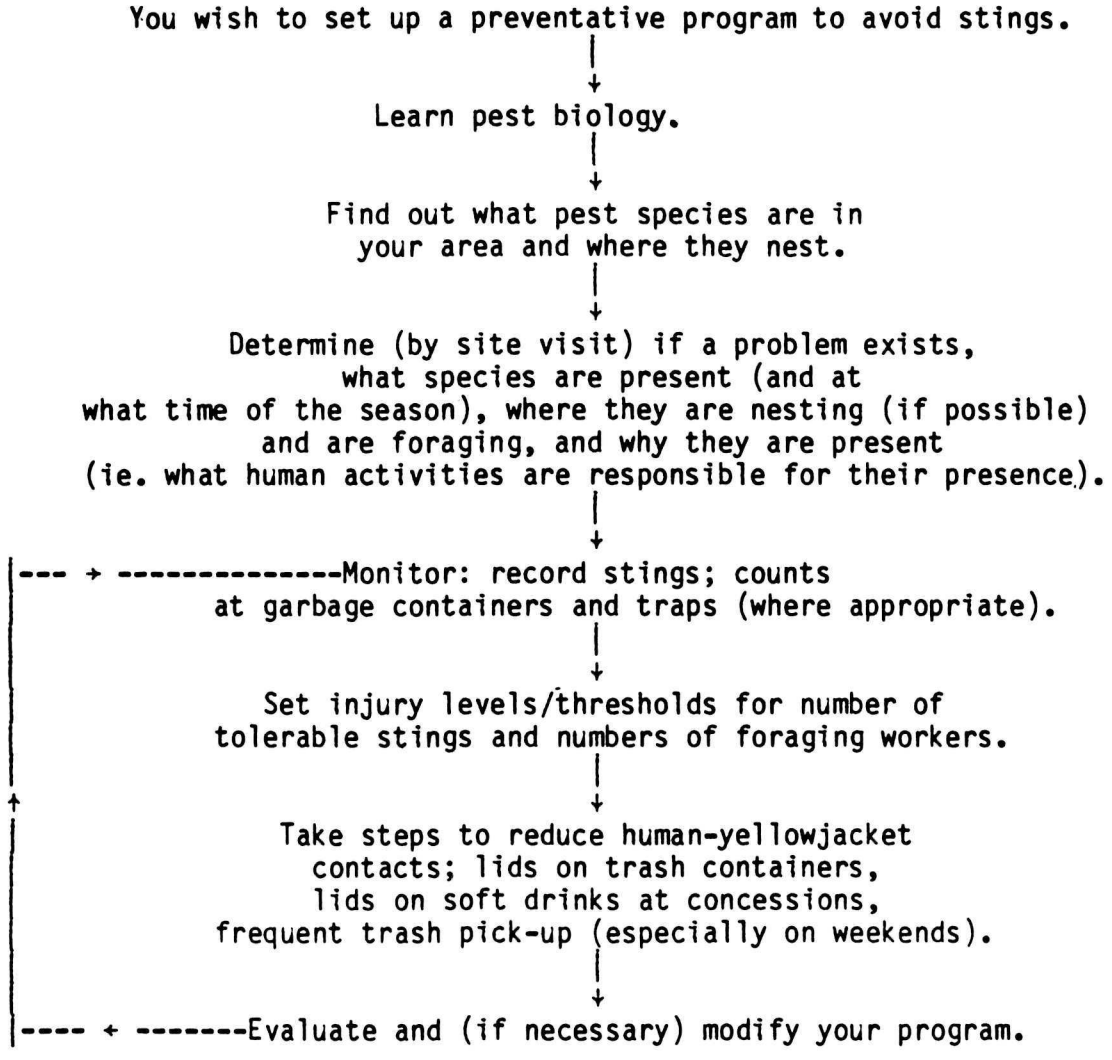
I. YELLOWJACKET IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to EPA label instructions and be approved on annual basis by the Director, NPS.




Someone has just been stung.
Ask if they are sensitive to wasp or bee venom and observe them for symptoms of sensitiviy.
Is the victim sensitve?
NO
YES
Get the victim to hospital or get emergency help immediately (death may occur in some individuals from anaphylactic shock within 10 minutes). If medical assistance cannot be reached immediately, administer emergency medical treatment (including injections of medication if you are certified).
Record the the sting occurance.
Victim is not sensitive.
Provide sting first aid.
Advise victim to report the sting to a doctor.
Provide information on how to avoid stings.


A nest has been found in a location which poses a threat to visitors or personnel (e.g., along a trail, in a structure, or hanging from a tree, under eaves or other object).
Is nest underground?
NO
YES
To eliminate nests, the following procedure should be followed:
- Destroy the nest by vacuuming.
- Use pesticide (Wasp-freeze®) to destroy the nest.
Evaluate treatment.
To eliminate nests, the following procedure should be followed:
- Check with local bee keepers who may collect nest for later sale for venom extraction.
- Destroy the nest by vacuuming.
- Destroy nest by applying regestered pesticide (Wasp-freeze®).
- Remove dead colonies if possible, and eliminate entrances in structures.
Evaluate treatment.


You wish to set up a preventative program to avoid stings.
Learn pest biology.
Find out what pest species are in your area and where they nest.
Determine (by site visit) if a problem exists, what species are present (and at what time of the season), where they are nesting (if possible) and are foraging, and why they are present (ie. what human activities are responsible for their presence).
Monitor: record stings; counts at garbage containers and traps (where appropriate).
Set injury levels/thresholds for number of tolerable stings and numbers of foraging workers.
Take steps to reduce human-yellowjacket contacts; lids on trash containers, lids on soft drinks at concessions, frequent trash pick-up (especially on weekends).
Evaluate and (if necessary) modify your program.

II. YELLOWJACKET BIOLOGY AND ECOLOGY

1. Species Described:

Yellowjackets (*Vespula*, *Dolichovespula*, *Vespa*) are colonial wasps which build enclosed paper nests underground, in trees or structures. While many other species of wasps, such as paper wasps (*Polistes*), may build nests in dangerous places (i.e.: under building eaves), they are not considered pestiferous in most circumtances.

Of the 19 species of yellowjackets and hornets found in North America, only 5 are considered to be pestiferous:

A. Eastern yellowjacket - *Vespula maculifrons* (Buysson)

B. Southern yellowjacket - *V. squamosa* (Drury)

C. German yellowjacket - *V. germanica* (Fab.)

D. Common yellowjacket - *V. vulgaris* (L.)

E. Western yellowjacket - *V. pensylvanica* (Saussure)

Other species may from time to time become troublesome or (more commonly) build nests in dangerous places (along trails, under eaves, etc.). The species considered pestiferous are all scavangers (especially late in the year) and foragers which come into contact with people frequently. All yellowjackets, including scavenging species, should be considered beneficial due to their predaceous habits and their consumption of large quantities of insects.

See pages 100-119 of U.S. Department of Health, Education, and Welfare (1967) for keys to stinging hymenoptera of the U.S. Also see Akre et al. (1981) for detailed keys to yellowjackets of North America.

2. Geographic Distribution:

A. Eastern yellowjacket - Eastern to central U.S., rarely to Colorado.

B. Southern yellowjacket - Southeastern U.S., north to Pennslyvania, west to central Texas and Iowa.

C. German yellowjacket - Introduced from Europe, Northeastern U.S. Moving west, reported from Illinois and Ontario to Georgia.

D. Common yellowjacket - Northern North America, south in Appalachians to Georgia, south on Pacific Coast to Los Angeles, south in Rockies to Mexico. Introduced to Hawaii (Maui).

E. Western yellowjacket - Western U.S. to Nebraska, rarely to Wisconsin. Introduced to Hawaii (Kawai, Oahu, Maui, Hawaii).

3. Habitat:

A. Eastern yellowjacket - Nests mainly in ground, occassionally in wall voids. Queens overwinter in rotten logs or soil litter and begin a new colonies in abandoned rodent burrows or in air pockets under logs or stones. Nests typically are located in forests and open areas, but the boundary between forest and field or path is favored. Nests are used only once.

B. Southern yellowjacket - Nests in ground, as per eastern yellowjacket; may be social parasite.

C. German yellowjacket - Nests almost exclusively in wall voids in North America; rarely subterranean.

D. Common yellowjacket - Nests in ground, rotten logs or stumps throughout range. May nest in walls in western U.S.

E. Western yellowjacket - Nests primarily in ground; may nest in attics or in walls.

4. Hosts:

A. Eastern yellowjacket - Feeds on insects for most of the year. Some foragers scavange dead insects and other animals, others capture live prey. Often scavanges sweets, especially when colony is at maximum population size late in the season.

B. Southern yellowjacket - This species often socially parasitizes nests of 4.A. (eastern yellowjacket), killing the resident queen and usurping the colony.

C. German yellowjacket - Same as 4.A. (eastern yellowjacket)

D. Common yellowjacket - Same as 4.A.(eastern yellowjacket)

E. Western yellowjacket - Same as 4.A.(eastern yellowjacket)

5. Life Cycles:

A. Eastern yellowjacket - The newly produced queens are the only members of the colony to survive the winter (except in some situations in Florida).

Sometime from late March to May, they emerge from hibernation. Fertilized by males the previous autumn, the queen lays approximately 45 to 70 eggs which will hatch and become the first generation of workers. The queen continues oviposition and forages and cares for her first brood. When the first 5 to 7 brood emerge, they function as workers and care for all subsequent brood. The queen does not leave the nest again. Workers feed the young, expand the underground nest by digging (the queen does not dig), produce paper comb, and protect the nest. Unlike bees, where worker age determines duties, yellowjackets can and do perform all duties at all ages (Davis, 1978). Also unlike bees, yellowjacket workers are not sterile but are kept from laying and caring for their own progeny by inhibitory chemicals (pheromones) produced by the queen. If the queen is lost, workers will produce male offspring.

B. Southern yellowjacket - Same as 5.A.(eastern yellowjacket)

C. German yellowjacket - Same as 5.A.(eastern yellowjacket)

D. Common yellowjacket - Same as 5.A.(eastern yellowjacket)

E. Western yellowjacket - Same as 5.A.(eastern yellowjacket)

6. Seasonal Abundance:

A. Eastern yellowjacket - Colonies grow slowly until mid-summer when successive broods of workers emerge and growth becomes exponential. Pest species typically have 500-5,000 workers at peak population. In late summer, new queens and males are produced. Queens mate and go into hibernation. After queens and males have left, the colony declines in population, with fewer workers being produced. Existing brood are usually discarded or fed to other larvae in the colony. Foraging workers are more likely to sting at this time.

Maximum worker numbers result in many workers foraging in picnic areas and trash cans for discarded soft drinks and other foods. Increased activity in areas frequented by human beings, coupled with increased aggressiveness and willingness to sting, leads to a sharp upsurge in the number of stings in late summer and fall (Davis, 1978).

With the advent of cold weather, the old queen and workers die (the mated queens go into hibernation very early).

B. Southern yellowjacket - Same as 6.A.(eastern yellowjacket)

C. German yellowjacket - Same as 6.A.(eastern yellowjacket)

D. Common yellowjacket - Same as 6.A.(eastern yellowjacket)

E. Western yellowjacket - Same as 6.A.(eastern yellowjacket)

7. Response to Environmental Factors:

Yellowjacket populations are influenced by weather. Cold, wet winters are unimportant, but sudden cold snaps in springtime may severely reduce colony survival. In studies with western species it has been demonstrated that cold periods during the critical first brood phase are the most important single factor determining yellowjacket abundance (Davis, 1978).

Queens compete for nesting areas in early spring. Several queens may attempt to usurp the nest of another and it is not uncommon to find the carcasses of more than one queen in the entrance of a small nest.

8. Medical importance:

8.1. Direct Effects:

Those individuals who are not sensitive to venom experience intensive burning, followed by swelling and itching at the sting site. Treatment consists of application of analgesic gel or ice to relieve pain and reduce swelling. Household meat tenderizer is sometimes used to degrade venom proteins.

Approximately 0.4-0.8% of the human population is sensitive to wasp venom. When these individuals are stung, reactions can range from itching and burning at the site of the sting (the common reaction of non-sensitive individuals), through several intermediate stages, ultimately to coma and death. Delayed reactions in sensitive individuals may occur up to 96 hours after the sting occurred. (See Akre et al. 1981, and Frazier 1976, for details). Anyone exhibiting symptoms of sensitivity, or with a history of reaction to stings, should be transported to the nearest medical facility as soon as possible. If qualified, park personnel may begin emergency treatment if necessary.

8.2 Indirect Effects:

The major indirect effect of yellowjackets is the fear of being stung, particularly when flying yellowjackets are common. Anxiety and nuisance have resulted in auto accidents, lost work, and lessened enjoyment of the outdoors by park visitors.

8.3 Sting Therapy:

Immediately following the sting, intense burning is experienced at the site of the sting, followed after several minutes by swelling and intense itching. The swelling may be localized to a few centimeters immediately surrounding the sting, or may involve an entire extremity or other part of the body.

Ice or cold compresses on the sting site relieve burning and itching. Applying a meat tenderizer containing papain will also relieve some symptoms. (The enzyme in meat tenderizer breaks down proteins which are the major components of venom). Antihistimines may be administered as well in more severe cases.

Symptoms of a generalized systemic reaction may range from mild to severe. Frazier (1976) stated, "Such reactions can be delayed, presenting serum sickness-like symptoms of fever, headache, malaise, rash, lymphadenopathy, and polyarthritis. It is an immediate reaction, however, that presents the physician with a medical emergency. Even a slight systemic reaction with symptoms of generalized rash, itching, malaise, and anxiety should be assessed and treated on a long-term basis in the realization that the next time the patient is stung the results may be far more serious, even life-threatening.

"A moderate systemic reaction may be marked by any of the symptoms mentioned above and two or more of the followings: (1) constriction of throat or chest; (2) abdominal pain, nausea, vomiting; (3) dizziness; (4) wheezing; and (5) generalized edema.

"A severe systemic reaction may include any of the above symptoms and two or more of the following: (1) labored breathing; (2) difficulty in swallowing, hoarseness, or thickened speech; (3) weakness; (4) confusion; and (5) a feeling of impending disaster.

"A shock or anaphylactic reaction would include any of the above symptoms in addition to two or more of the following: (1) lowered blood pressure; (2) cyanosis; (3) collapse; and (4) unconsciousness."

In severe reactions, subcutaneous injection of epinephrine (1:1000) at .02-.05 ml dosage is prescribed (maximum 0.03 for children). Injections should only be administered by a physician or qualified emergency medical technician. Any park which does not have access to a hospital should have qualified Emergency Medical Technicians (EMTs) on staff. Contact your park or regional health and saftey officer for further information.

Kits are available by prescription which contain a preloaded syringe of epinepherine, antihistamine tablets, phenobarbital tablets and directions for use.

9. Natural enemies:

Yellowjackets are preyed upon by birds and some mammals(especially skunks which may dig up and consume several nests in a single night). A parasitic wasp invades colonies, laying its eggs on and destroying yellowjacket larvae. Yellowjackets are also sometimes affected by nematodes and pathogens which destroy brood and workers.

III. YELLOWJACKET MANAGEMENT

1. Population Monitoring:

The objective of an IPM program for yellowjackets is not eradication, but separating yellowjacket and human populations to minimize interaction (i.e. stings). Therefore, pest yellowjackets are monitored in specific areas of human activity rather than on an area wide basis. Trails, picnic areas and trash cans are some of the areas which should by monitored. See Giraldi and Hackett (1982) for specific techniques for monitoring in special circumstances.

Monitoring trails and picnic areas consists of visual inspections for flying yellowjackets and nests. Trash, especially soft drink or beer containers, will attract foragers late in the season.

Trash cans are monitored by counting the number of visiting foragers in a 10-minute period, several times a day, on a daily basis late in the season.

Stings should be recorded either on standard NPS Case Incident Record Forms, or the sting form on page 19. The sting form is usually better because more detailed information can be provided. Recording sting information provides data on where in the park the most stings occur and where special efforts should be made in implimenting the IPM program. Data from the sting form will also indicate what sort of problem exists (e.g., a single sting received on the foot while walking barefoot in a grassy area is probably due to a bee, while stings on the hands or face while eating are due to yellowjackets). Multiple stings on the legs or ankles usually indicate that the victim has disturbed a ground nest. First aid is also recorded; a copy may be made for the victim to take to their doctor. Sting data also provide an evaluation of the success of the IPM program.

2. Threshold/ Action Population Levels:

Threshold levels and action populations will vary from park to park, as well as throughout the season. A park which has several incidents of stings each season may be more (or perhaps less) tolerant of high yellowjacket populations than a park in which only a few stings are reported. Any area which has had a death or near death occur from stings will also have a lower tolerance threshold to yellowjacket numbers.

As the season progresses and yellowjacket numbers increase, tolerance will proportionaly decrease.

Wagner (1961), has determined that 15 foragers visiting an open garbage can in 10 minutes is indicative of a severe yellowjacket problem.

If, for example, stings increase when counts of foragers visiting garbage containers are 10 yellowjackets in 10 minutes, you may wish to set action levels at 5 yellowjackets in 10 minutes. Action might include more frequent garbage pickup, washing cans, or using insecticides in cans (see sections III.3., and III.4.). Good record keeping and sampling will enable you to eventually correlate stings with numbers of foragers and set treatment levels which are unique for your park.

3. Management Alternatives - Nonchemical:

The basis for non-chemical management is to separate human and yellowjacket populations in order to reduce contact between them.

1. Public education - Displays, handouts and other information should be presented to inform the park visitor that wasp stings are mostly avoidable if a few precautions are followed. Educational materials should emphasize the place wasps have in the overall park environment. See the sample education flier, page XLVI-23.

2. Refuse management - All refuse containers should be solid "tulip type" (no wire mesh) plastic or metal containers and equipped with wasp-tight lids to prevent foragers from gaining access to the interiors. All containers should be checked regularly for gaps and holes. Refuse should be collected on a regular basis before containers are full. This may entail collection several times a day, particularly in picnic areas and during period of heavy park use, such as weekends. Containers should be cleaned or washed regularly to reduce attractive odors.

3. Concessions cooperation - All beverages sold by concessions in the park should be supplied with plastic lids on cups and straws. This prevents foraging wasps from crawling into the cups as well as reducing their attractiveness (odor) to foragers. In addition, spillage is reduced when the cups are discarded by the visitor.

In one Eastern park where these simple management steps were taken, the number of stings dropped from 57 in one year to 2 the following year, a reduction of over 95% (see Giraldi and Hackett, 1982).

4. Trapping - Traps can temporarily reduce the number of foragers in an area. It should be noted however that an individual colony can have up to 5000 workers in normal circumstances (in tropical or subtropical regions, one periennial colony may contain over 1 million workers), so trapping at best affords only temporary relief in limited areas.

   Funnel traps using synthetic lures (such as heptyl butyrate) have been used successfully to capture western yellowjackets, reducing local densities to tolerable levels for short periods (Davis et al ,1973). Lures have not yet been proven useful against eastern species but research is continuing (Howell et al 1974). A problem with synthetic lures is their attractiveness to beneficial yellowjackets. While these lures may attract large numbers of insects, the percentage of pest species may be small.

   Temporary control of V. pensylvanica has been achieved (Akre, et. al.,1982) using traps consisting of raw fish (with the flesh exposed by cutting or breaking the skin) suspended above pans containing water and a wetting agent (to reduce surface tension). Yellowjackets visiting these traps typically cut large pieces of flesh from the hanging carcass, and attempted to carry them to sites where they can be trimmed to manageable sizes. The initial pieces were generally so large that the insects fell with them into the water and drowned.

   Advantages of the fish trap include ease of construction, effectiveness, and lack of toxicity. Disadvantages include the need to change the bait often (yellowjackets do not scavange spoiled flesh), and the attractiveness of the bait to dogs, cats, and wildlife; chickenwire cages can be placed around traps to provent damage by large animals. In a 1973 test (Akre et. al.,1982), 9 traps set up in a resort area captured nearly 1000 foraging workers per week. Trapping and improved

garbage management reduced the number of active foragers in the area to tolerable levels within two weeks.

5. Biological control - Biological controls against yellowjackets do not yet exist. Naturally occuring parasites and predators have little or no effect on colony dynamics. Destruction of overwintering queens attempted in New Zealand and Cyprus, showed no effect on populations the next spring (Akre et. al.,1982). Yellowjacket colonies produce large numbers of queens, most of whom do not survive to found new colonies. It has been estimated (Spradbury, 1973) that natural mortality of new queens and new colonies approaches 99.9%. Destruction of queens in winter may actually increase the number of successful colonies by reducing queen competition for suitable nesting sites in spring. Poinar and Ennik, (1972) used parasitic nematodes for yellowjacket reduction with some success experimentally. In the wild, conditions within the colony make survival and dispersal of nematodes difficult at best. Few positive data exist for field trials.

6. Mechanical control - In situations where chemicals cannot be used for underground nest destruction, 2 workers (in bee suits, using a cannister type vacuum cleaner) can excavate and destroy a colony in a few minutes. Vacuuming destroys workers, comb, and brood. Vacuum bags are plugged and frozen to kill the contents.

All nonchemical control measures (especially garbage management, lids on refuse cans, and lids on soft drinks) should be in place before yellowjackets become abundant late in the season. Yellowjacket foragers return to the same food source many times, and cutting off food sources late in the season may result in large numbers of aggressive workers flying around trash cans.

4. Management Alternatives-Chemical:

Due to the large numbers of colonies and workers usually found in most areas, area wide chemical control of foragers is impractical, if not impossible. However, individual colonies, in hazardous locations can be destroyed by chemical means. Nest destruction should be only attempted after dark when most of the foragers are in the nest and activity has ceased.

Anyone attempting to destroy a subterranean or structural nest should wear a bee suit and take further precautions against stings.

1. Underground nests - Subterranean colonies can be destroyed by pouring insecticides into the entrance, which is then plugged with cotton or steel wool. The plug and surrounding area should be treated to destroy returning foragers which have spent the night outside the colony. Aerosols containing pyrethins, rotenone, and a cooling agent (Wasp-Freeze®) to lower activity may also be used; see Akre et al (1982). Use of gasoline for nest destruction is not recommended.

2. Aerial nests - Several products are sold for aerial nest destruction. These contain a cooling agent or a pesticide which provides rapid knockdown. Aerial nests should only be destroyed at night.

3. Nests in structures - Yellowjackets nesting in walls are difficult to control, but success has been reported by researchers using pyrethroids blown into the entrance hole, which is then plugged with steel wool treated with 1 oz. of 5% carbaryl dust. Yellowjackets trying to escape, as well as returning foragers contact the material and die. Structural nests may be destroyed by this method during daylight hours. See Nixon (1982), for details.

In colonies not treated (i.e.: healthy colonies), the entrance hole should not be plugged. If the hole is plugged, a heathy colony will chew a new hole through the wall, and emerge into living spaces. See Akre, et al (1980), and Nixon, (1982).

Insect growth regulators (IGRs) such as methoprene have been tested against the eastern yellowjacket and German yellowjacket with some

success (Parrish & Roberts 1983). Still experimental, this method shows promise for future application.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Plan for emergency care of sting victims who are sensitive to venom. Have first-aid facilities for nonsensitive victims. Monitor stings.

2. Establish garbage management programs inclucing wasp-tight covers on all refuse containers, and regular and frequent pick-up and removal. Wash containers if necessary. Monitor containers for visiting foragers.

3. Provide lids and straws on all soft drink containers sold by concessions; provide public education material on yellowjackets and wasps.

4. Destroy structural nests, ground nests, and aerial nests chemically if necessary.

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STING MONITORING FORM

Date:_____ Filed By:_____

1. Where in the park did the sting occur?

2. What was the victim doing when stung?
(example: walking on trail, throwing away trash, sitting at table, etc.)

3. How many times was the victim stung?

4. Location of sting(s) on victim's body:

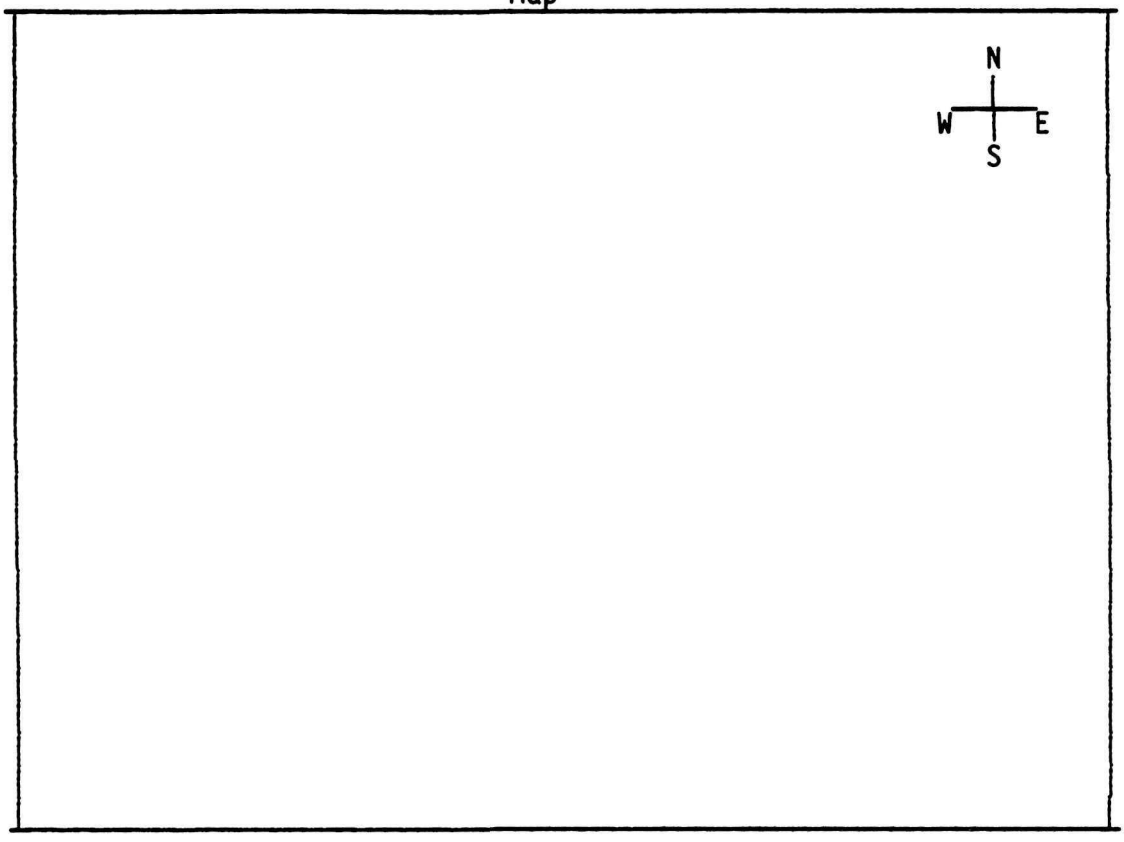
5. What was the reaction to the sting(s)?
(example: pain and redness, swelling in area of sting, swelling of limbs, nausea, respiratory distress, other)

6. What was follow-up treatment?
(example: application of gel, ice, referral to doctor, etc.)

7. Did victim receive printed materials on stings?

Yellowjacket Monitoring Form

Map



Date:_____ Map Reference #:_____ Recorder:_____
Weather/Temperature:_____
Park Location:_____
Park Use: picnic area, path, recreation area, forested area, other_____
Yellowjacket/wasp species observed and their behavior:_____

Food and waste management practices:

1.	Are concessions providing lids and straws for beverage containers?	y	n
2.	Are garbage containers wasp-tight?	y	n
3.	Are garbage cans overflowing because garbage is not collected frequently?	y	n
4.	Are there enough garbage cans?	y	n
5.	Are spills cleaned up or hosed down?	y	n

Counts of yellowjackets visiting a garbage can in 15 minutes:
(Identify the can on the map)
Presence of active nests:
Where: (identify on the map)

Treatments:

Comments/Recommendations:

COUNTS OF YELLOWJACKETS VISITING GARBAGE CONTAINERS

Park:

Recorder

Date:

Time of Day:

Weather/temperature (sunny, stormy, etc.):

Where can is located*:

Number of yellowjackets observed visiting the can in 15 min.

Yellowjacket species observed:

*An alternative to this form is to draw the park location where garbage containers are to be monitored. This picture will help prevent confusion as to which container was monitored. Monitoring data can be placed right on the form.

YELLOWJACKET STING SHEET

Yellowjackets are small colonial wasps which normally nest in the ground. In late summer, colonies are at maximum size. Workers are common in picnic areas and around trash cans where they hunt for sweets. Yellowjackets sting readily and a worker may deliver more than one sting.

YELLOWJACKETS ARE ATTRACTED TO:

1. Perfumes and other scents
2. Hairspray
3. Suntan lotion
4. Cosmetics
5. Brightly colored clothes
6. Sweets

WAYS TO DECREASE STINGS:

1. Don't go barefoot
2. Don't swat with your hands
3. Avoid using things yellowjackets are attracted to
4. Use lids on soft drink cups
5. Put tight fitting swing type lids on trash cans
6. Have frequent trash can pick up

STINGS

In most people, a yellowjacket sting produces an immediate pain at the site of the sting. There will be localized reddening, swelling, and itching. Ice or analgesic creams often relieve the symptoms.

IF YOU ARE STUNG:

1. Remove the stinger by scraping from the side (for bees)
2. Apply cold water or ice in a wet cloth
3. Lie down
4. Lower the stung arm or leg
5. Do not take alcohol

Some people experience an allergic reaction to yellowjacket venom. Allergic (anaphylactic) shock can be fatal if untreated. Symptoms usually occur 10-20 minutes after a sting but may appear up to 20 hours later. If you experience any of the following symptoms after being stung, obtain medical aid immediately:

SYMPTOMS OF ALLERGIC REACTIONS:

1. Hives
2. Wide-spread swelling of limb
3. Painful joints
4. Wheezing
5. Faintness
6. Dizziness
7. Vomiting
8. Abdominal cramps
9. Diarrhea
10. Shortness of breath
11. Nasal discharge or stuffiness
12. Tightening of throat

WHAT TO DO:

1. Lie down; victim should not be moved
2. Lower the stung arm or leg
3. Apply ice
4. Do not take alcohol
5. Apply rubber bands or wide cloth above the sting between sting and heart (should be able to place 2 fingers under bands); remove after 5 minutes
6. GET MEDICAL AID

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