GREAT BASIN NATIONAL PARK

Lehman Orchard

Management Plan

January 1990

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ACKNOWLEDGEMENTS

The idea to first develop a management plan for the historic Lehman Orchard began many years prior to the establishment of Great Basin National Park while the orchard was part of Lehman Caves National Monument. This plan relies heavily on the first draft plan for the orchard, developed in 1986 by Stewart Vaughn, Steven Riley and Albert J. Hendricks. Additional appreciation is extended to Harlan Unrau, who, through his studies of the History of the Great Basin National Park area, contributed significantly to our understanding and awareness of the Lehman Orchard resources. Harlan contributed unselfishly to the review and revision of the History section of this plan. We have used his text, virtually unaltered, as the background history of the plan.

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INTRODUCTION

The Lehman Orchard is a small stand of fruit trees located just east of the Lehman Caves visitor center in Great Basin National Park (Figure 1). The area was placed on the National Register of Historic Places in 1975 as representative of an "early agricultural accomplishment, based on irrigation in an area more suitable for cattle grazing (Regional Director 1975)." The remnant orchard that exists today consists of seven apricot trees and a peach tree. Although quite old, the trees continue to produce fruit.

This document is concerned with the overall management of the orchard and techniques to perpetuate its historic genetic resources. Although restoration of the original historic scene is not practical nor recommended, aesthetics and historic interpretation have been considered in formulating management actions.

HISTORY (Unrau 1989)

The best known of the early settlers in Snake Valley was Absalom S. Lehman, who would later gain renown as the discoverer and early developer of Lehman Caves. Some doubt exists concerning the exact year of his arrival in the valley; family accounts infer that this may have been as early as 1866 or 1867. A military map prepared by the George M. Wheeler expedition in 1869 shows a Lehman Ranch on Weaver Creek, some ten miles north of present-day Lehman Caves (Hamel 1869).

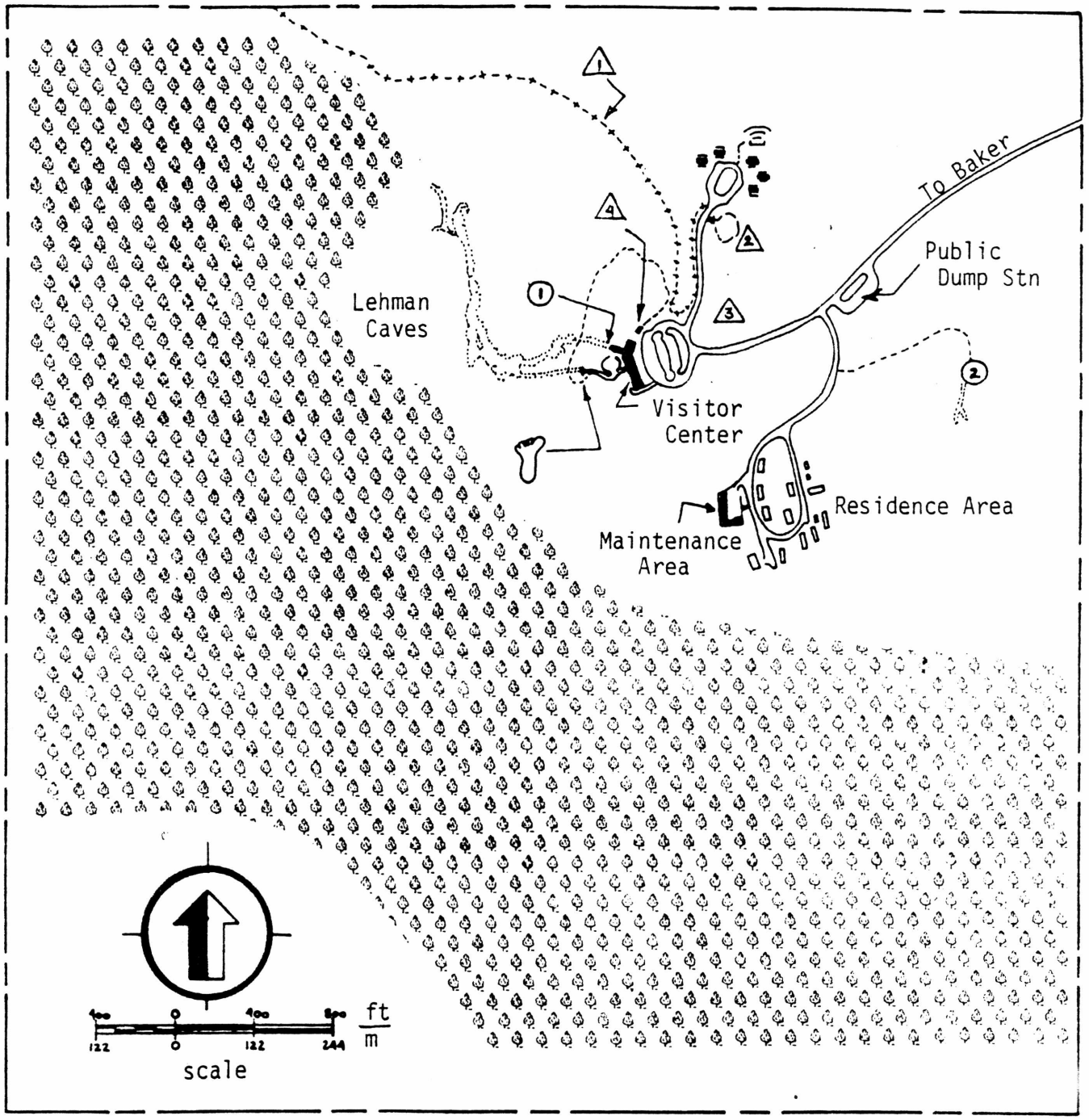
Little is known of Lehman's ranch on Weaver Creek, which he soon sold to David Weaver. Later in 1869 at the age of 42 he returned to Ohio, where he had lived as a youth, and married 21 year-old Olive Smith, his first wife having died in 1861 while they lived in Australia developing a gold mine and operating several woolen stores. By the fall of 1870 Lehman was back in Nevada living in a large meadow area along Lehman Creek about 1-1/2 miles below present-day Lehman Caves.

By 1875 Lehman and his brother Ben, who settled at the site of present-day Baker in 1873, had developed a partnership to operate a dairy in addition to a fruit orchard and large garden. They had 25 to 30 cows and churned butter using a water wheel Absalom had constructed in Lehman Creek. The Lehmans sold products from their ranch to mining camps throughout the area. The large garden and orchard were supplemented with wild fruits, especially strawberries. The partnership was dissolved in June 1877, and by 1880 Absalom had hired two hands to help him operate the growing ranch (Mellanbruch 1943).

The first formal land survey in Snake Valley was conducted by W.N. McGill on November 28-29, 1878, for the U.S. Coast and Geodetic Survey. The survey map produced by McGill shows that the Lehman Ranch was located along Lehman Creek about four miles west of present-day Baker and indicates that Lehman had used the waters of Lehman Creek continuously since 1869 (McGill 1878).

Absalom returned to Snake Valley in September 1883 after spending time with his wife in Ohio before her death from Tuberculosis. Although documentation is inconclusive as to the exact date and circumstances of Lehman's discovery

Figure 1. Location of Lehman Orchard



SYMBOLS USED

- LEHMAN DITCH
- LEHMAN POND
- LEHMAN ORCHARD
- RHODES CABIN
- LEHMAN CAVE ENTRANCE
- LITTLE MUDDY CAVE
- SUBTERRANEAN PASSAGEWAYS
- PICNIC AREA
- AMPHITHEATER
- MOUNTAINVIEW NATURE TRAIL
- PAVED ROADWAYS

of the cave that would bear his name, it is generally agreed that he made his discovery during the spring of 1885 (Mellanbruch 1943). Lehman soon began to advertise his discovery, develop the cavern, and serve as a guide for persons wishing to tour the cave (White Pine Daily News 1885).

Lehman continued his farming operations while developing the cave. The primary markets for his agricultural produce continued to be the various mining communities, such as Osceola and Black Horse, in eastern Nevada (White Pine Daily News 1886).

Sometime after discovering the cave Lehman decided to sell his ranch on Lehman Creek and move to a small 7-acre site just below the mouth of the cavern. This small parcel would later be developed as his "Cave Ranche," at the location of the historic orchard. The move would permit him to devote more of his time to developing the cave, guiding and entertaining tourists. As early as mid-October 1887 Lehman began listing advertisements in local newspapers that his lower ranch was for sale. The advertisements described the extensive development of his lower ranch on Lehman Creek and appeared periodically in newspapers for almost four years. The ranch, according to the advertisements, contained 600 acres:

> "Of choice meadow and arable land, and is well-watered by a never-failing spring sufficient to irrigate 500 acres. The ranch is well-fenced by six miles of fencing, and is conveniently subdivided into hay meadows, pasturage, orchards, and cultivated fields. There is a fine young orchard of 800 trees.
>
> Of different fruits on the place, one hundred of which are now bearing, and the rest will soon be. The ranch is well supplied with outbuildings, comprising stables, blacksmith shop, carpenter shop, butcher shop, and is also well-equipped with an abundant supply of the best corrals. It is one of the finest dairy ranches in this section of the country, and has a good Rock Milk House, with all the necessary equipments, including a churn run by water power" (White Pine Daily News 1888).

While attempting to sell his home ranch on Lehman Creek, Absalom apparently began developing his upper "Cave Ranche". Documentation is inconclusive, but it seems likely that Lehman began planting a fruit orchard and grazing cattle below the mouth of the cave at some point during the mid-1880's. Available documentation does not provide data on the kinds of trees or size of the orchard planted by Lehman near the cave.

Lehman's orchard and grazing operations at his "Cave Ranche" required irrigation water. Thus, sometime around 1887 he constructed what has come to be known as the Lehman Ditch or Aqueduct, using earth and rock dams and wooden gates to collect and divert water from Cave Spring, Lehman Creek, and South Spring to his "Cave Ranche" (Dunn 1940).

Lehman finally sold his ranch on Lehman Creek to Charles W. Rowland for $3,000.00 on September 1, 1891. Rowland and his family had recently moved to Garrison from St. George, Utah. Absalom soon became ill with the grippe, however, and on October 11 he died of complications resulting from pneumonia

at St. Mark's Hospital in Salt Lake City (White Pine Daily News 1891).

Apparently, Lehman's "Cave Ranche" was largely undeveloped at the time of his death, the tax assessment books for White Pine County in 1891 and 1892 listed the following details of his 7-acre ranch near the cave (White Pine County 1891-92).

1891
7 acres at Lehmans Cave with improvements

Value of Real Estate - $7
Value of Improvements - $200

1892

Estate of A.S. Lehman
7 acres of land known as the Lehman Cave Ranch with improvements

2 work horses	$100
25 stock horses	$250
3 stock cattle	$ 35
Value of Real Estate	$ 40
Value of Improvements	$200
Value of Personal Property	$385
Total Value	$625

On November 15, 1892, the District Court of the State of Nevada, White Pine County, authorized the sale of the cave property by W.N. McGill, administrator for Absalom's estate. Pursuant to the court order McGill announced that a public auction would be held on April 1, 1893, at which the personal property and other interests of Lehman were to be sold. The advertisement for the public auction read (White Pine Daily News 1893):

> "At one o'clock p.m., at the Lehman Ranch, near Lehman's Cave, in said county, the following personal property to wit:
>
> The Farming Implements, Household Furniture, Kitchen Utensils, Six Thousand Shingles, One Set Hewed House Logs, Spring Wagon, one Cart, two Cows, one calf, fourteen Brood Mares with seven Colts, four three-year old Colts, two Horses, ten two-year old Colts, and one Stallion.
>
> Also, all the right, title, interest and estate of the said A.S. Lehman at the time of his death, or the said estate has since acquired, in and to that certain lot, piece or parcel of land, situate, lying and being in the said County of White Pine, and known as the A.S. Lehman's Ranch, and the improvements thereon, which said Ranch is situated about twenty miles from Osceola, as being the land occupied by the said A.S. Lehman at the time of his death.
>
> The terms and conditions of said sale are cash or its equivalent on delivery of possession."

Because Absalom had never filed a homestead claim on his 7-acre "Cave Ranche", his alleged title to the property was apparently questioned. Thus, the land was not sold at the auction. Finally, on November 20, 1895, the "Cave Ranche" was sold for $700 to Rowland, the purchaser of Lehman's 600-acre ranch several years earlier. Rowland maintained the two ranches until his death in January 1905, apparently planting additional trees in the orchard near the cave and perhaps constructing or enlarging the pond or reservoir at the "Cave Ranche". An article in the White Pine Daily News on September 4, 1897, described several events on the Rowland properties:

> "The vandals who have made it a business to rob orchards, still keep up their reputation. The orchard on the Cave ranch, belonging to C.W. Rowland, was robbed of over two hundred pounds of pears, last week. Mr. C.W. Rowland has treated himself to a new cider mill. He promises the people of Ely some good cider in a few days."

After Rowland's death in January 1905, his wife held the two ranches until 1911 when she sold them to P.M. (Doc) Baker, the son of George W. Baker who had earlier established the Baker Ranch in Snake Valley. In 1905 the White Pine County Assessment Books had the following listing for the estate of Charles W. Rowland.

> Home Ranch on Lehman Creek - 600 acres and 7 acres on Cave Creek
> Furniture - $50
> Organ - $40
> Work & Saddle Horses - $150
> Harness - $40
> Milk Cows - $100
> Stock Cattle - $1,690
> Hogs - $50
> Wagons & Machinery -$ 170
> $2,290

The following year both the 600 and 7 acre ranches were listed under the name of Mrs. C.W. Rowland in the county assessment books, and in 1908 the 600-acre ranch was described as consisting of 150 acres of cultivated land and 450 acres of pasture and brush. In 1910, the year before Mrs. Rowland sold her two ranches to Baker, her property as listed in the county assessment books consisted of furniture, an organ, one work horse, two stock horses, a harness, two cows, eight stock cattle, five hogs, wagons, and machinery (White Pine County 1905,1906,1908,1909,1910).

Little is known about the operation, maintenance, or productivity of the Lehman Orchard between 1911 and 1934. On October 12, 1912, Lehman Caves and the lands surrounding Lehman's "Cave Ranche" were added to the Snake Division of Nevada National Forest (President of the United States 1912). By 1916 E.C. Adams had been hired by the U.S. Forest Service as the caretaker of Lehman Caves and was living in a house some 150 to 200 feet below the mouth of the cave (Winkler 1916). According to one long-time resident of the area Adams maintained the orchard and planted alfalfa in the fields below the orchard in addition to serving as custodian and tour guide for the cave (Virginia Eldridge personal communication).

On April 7, 1916, Adams had the land which consisted of 47.46 acres below the mouth of the cave, surveyed by Forest Service Surveyor C.P. Thompson (Figure 2). The property included a house, an orchard with a barn located near its southwest corner, a reservoir, and the lower portion of the Lehman Ditch or Aqueduct (Figure 3). Adams finally acquired formal title to the land (Homestead Entry Patent No.724,083) on December 13, 1919, but his ownership was short-lived. Nathan Kiger and Clarence T. Rhodes became co-owners of the property in 1920 and Rhodes ultimately became sole proprietor in 1923 (Mellanbruch 1943).

Rhodes and his wife Beatrice apparently moved to the homestead property in 1920 and were officially designated the custodians of Lehman Caves National Monument in 1922. In a letter to NPS Director Stephen T. Mather in August 1928 Mrs. Rhodes described the property as it had appeared when they arrived:

> "We bought the little homestead here at the mouth of the caves from an old fellow who had just proved upon it shortly and who turned people loose to do as they pleased. There was an old cabin here that had been built by Abner [Absalom] Lehman who discovered the caves yrs. before and squatted here, also a remnant of an old orchard planted by him & nothing else..."

During the years between 1920 and 1928 the Rhodes made numerous improvements to Lehman Caves as well as their property. In the aforementioned letter Mrs. Rhodes observed that their ranch included "12 acres under cultivation, cows, horses, & ranch equipment". The twelve acres were "fenced in orchard & alfalfa," and the horses were available for "saddle trips to Wheeler Peak" (Rhodes 1928)

The Rhodes' land, together with the water rights to Cave Spring, were formally deeded to White Pine County on September 13, 1933. Five days later the property was conveyed to the federal government. The previous month (August 10) Lehman Caves National Monument had been transferred from the Forest Service to the National Park Service under the provisions of Executive Order 6166 signed by President Franklin D. Roosevelt on June 10. Thus, the Lehman Orchard came under the jurisdiction of the Department of the Interior.

A report and map prepared by the National Park Service in January and June 1934, respectively, indicate that the remnants of the Lehman Orchard consisted of some 40 apricot, apple, peach, and pear trees. The peach trees ranged in size between 16 and 24 inches in diameter and the apple trees up to 20 inches in diameter (Superintendent, Lehman Caves National Monument 1934).

Later in 1934 Civil Works' Administration personnel cut down and dug up many of the trees in the orchard because they were dead or dying as the result of drought and insect infestation. An NPS map (1938) plotted the exact locations of the remaining orchard trees and labelled according to species. A photograph taken in 1937 shows a small picnic area/campground in the orchard area, and a photograph taken in August 1940 shows a minimum of 18 trees and refers to the area as the "Apple Orchard". The picnic area remained in the orchard until at least the early 1950's, when most of the picnic tables were relocated adjacent to the Lehman Pond. In 1975 the Lehman Orchard, consisting

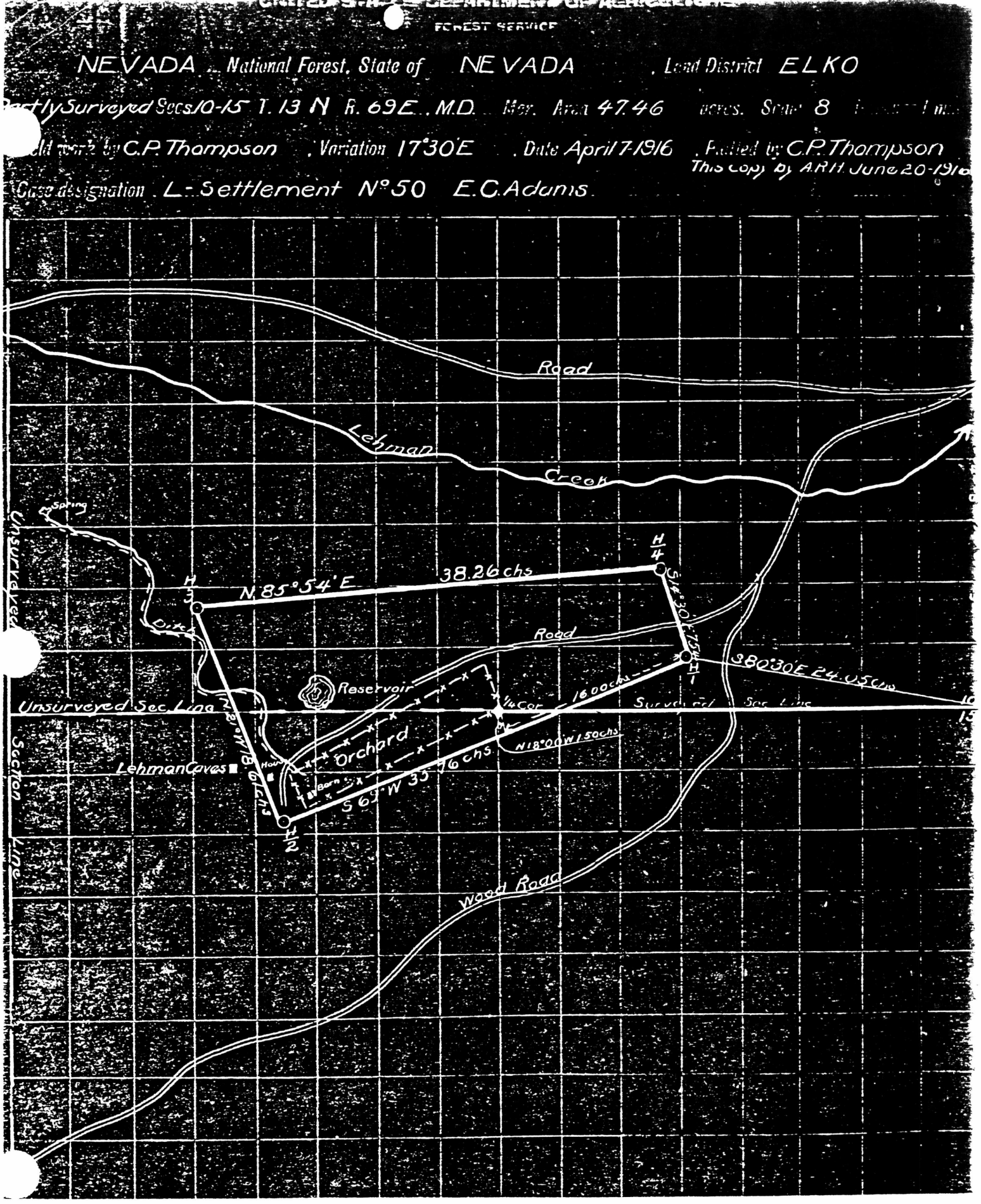


Figure 2. Cave Ranche Area Survey

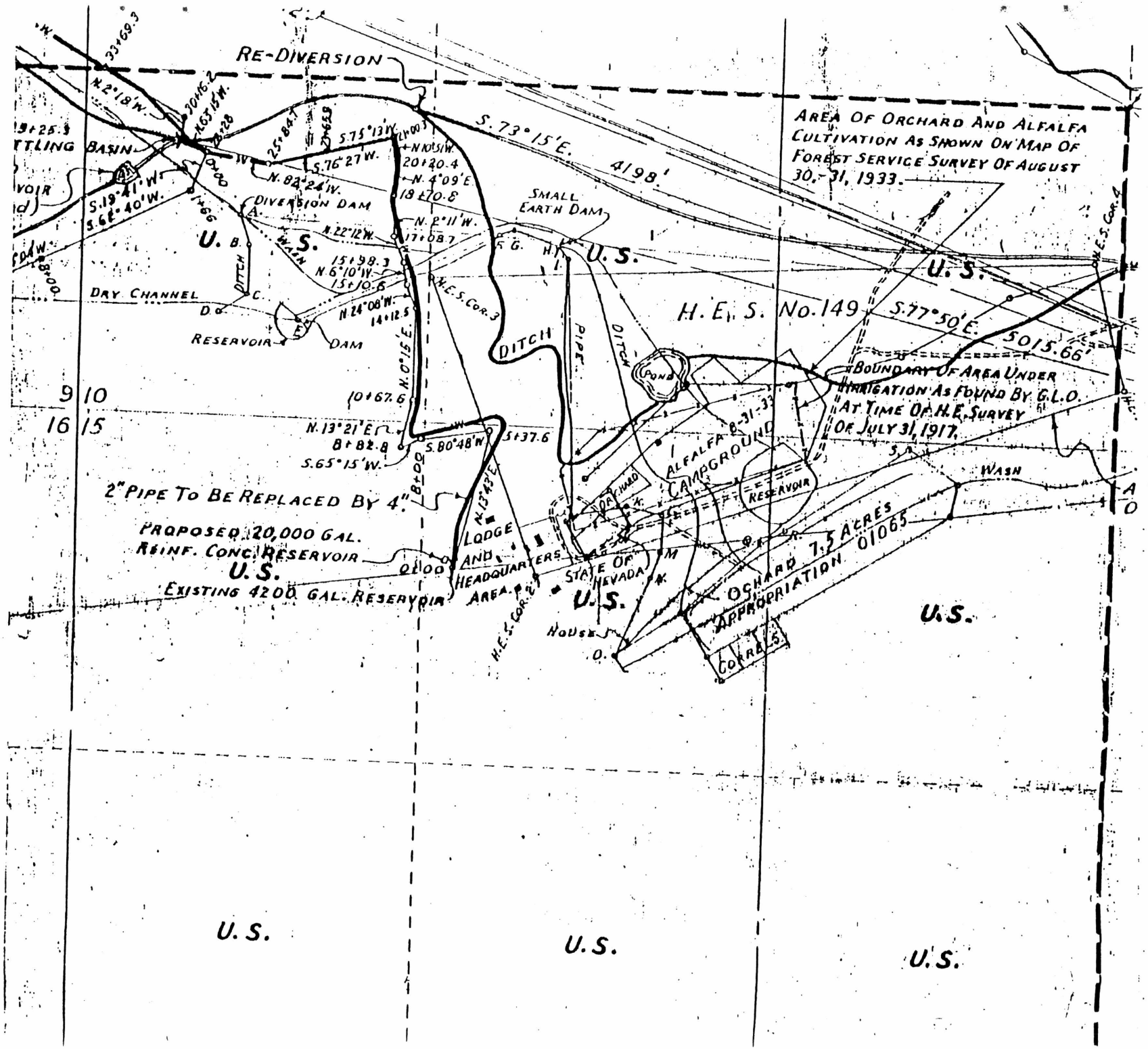


Figure 3. U.S. Forest Service Survey - Cave Ranche Area

of seven apricot trees, two pear trees, and one peach tree, was placed on the National Register of Historic Places (Regional Director 1975).

MANAGEMENT GOALS

By virtue of its designation as a National Register Site, Great Basin National Park is charged with managing the Lehman Orchard in such a manner that its historic character and fabric are maintained.

Though the site of the Lehman Orchard is significant, many alterations have taken place over the years which have compromised its historic integrity. For example:

1. The road and parking lot constructed in 1947 to access the Park's visitor center cut through a portion of the original orchard (Figure 4). One of these trees still remains in the parking lot median.

2. The pasture area adjacent to the orchard containing portions of the Lehman Aqueduct has been greatly disturbed as evidenced by the abundance of alien cheat grass.

3. The dam at the irrigation pond was breached in 1963 and later removed entirely and parts of the Historic Lehman Aqueduct have been obliterated by the road leading to the picnic area (Figure 4).

4. The legislation that created Great Basin National Park did not provide sufficient water rights for the NPS to flood irrigate the orchard as originally done by Lehman.

It is not the intent of this management plan to physically reconstruct the historic scene of the Lehman "Cave Ranche." Too many changes have taken place to make this either desirable or practical. It cannot be deciphered as to which owner (Lehman, Rowland, Adams, Kiger or Rhodes) made certain improvements. The area does, however, offer a wonderful opportunity for imaginative reconstruction through interpretation and this theme will be included in the Park's Interpretive Prospectus.

Today, a major significance of the Lehman Orchard lies in the genetic values of its fruit trees. These stately trees probably exceed 100 years of age and continue to bear the same varieties of fruit supplied to the early settlers of the Snake Valley. Through their fruit, these trees preserve a taste of history, genetically identical to their ancestors. Where historic varieties were primarily selected for flavor, commercial growers today are principally concerned with the ability to withstand storage and appearance. The genetic origin of the remaining trees is unknown and they are probably the last strains of the historic trees planted by Lehman and Rhodes. They are unique genetic resources worthy of preservation and perpetuation.

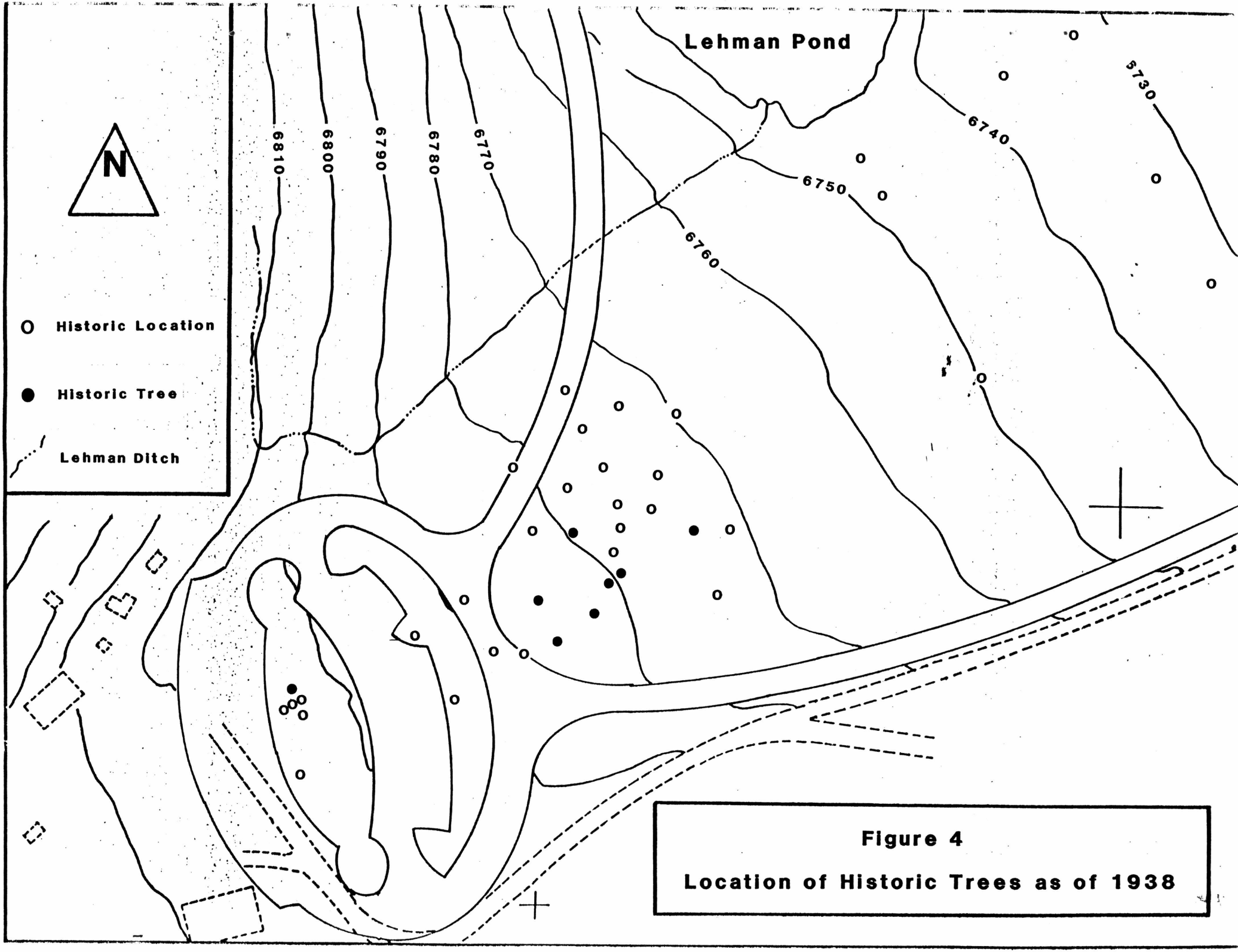


Figure 4

Location of Historic Trees as of 1938

The goals of managing the Lehman Orchard will be:

1. To protect and perpetuate the significant genetic resources that are present or were likely present in the historic Lehman Orchard. The emphasis will be on the protection of the historic trees and the perpetuation of the historic gene pool, and not primarily on the production and/or "quality" of fruit.

2. To perpetuate these cultural resources in an environmentally sound manner through the use of accepted Integrated Pest Management (IPM) and tree silvicultural practices.

3. To manage the area so that it blends aesthetically with its surroundings, with minimal distraction from the natural and historic character of the area.

4. To interpret to the visiting public the historic character and genetic significance of the Lehman Orchard and surrounding "Cave Ranche" site, and its role in the commerce of early Nevada ranching and mining towns.

MANAGEMENT ACTIONS: PLANTING AND REPLACEMENT

The trees of the Lehman Orchard are quite old, and the majority appear to belong to the same variety and genetic strain of apricot. This makes them extremely vulnerable to disease, insect infestations and future loss. An early map of the orchard (U.S. Dept. of Interior 1938),not included as a figure, shows the location of historic trees and labels them, by species (apple, apricot, pear and peach). Although the locations of the trees seem accurate, the identification of several of the existing trees is erroneous, suggesting that we may not rely on this map to identify missing species.

To prevent the loss of historic genetic material and to reintroduce the complement of historic species (apricot, peach, pear, plum, apple and crab apple), the Park will plant approximately 30 sapling fruit trees in the vicinity of the existing historic trees. The saplings will be grown from cuttings selected from the remaining historic trees and other species thought to be of the same historic stock as trees once found in the Lehman Orchard. These trees are located on the Rowland Springs ranch which Absalom Lehman operated concurrently with his small "Cave Ranche" located in what is now Great Basin National Park. Although no documentation can be found that conclusively links the trees of the Rowland Ranch to those of the "Cave Ranche," common sense dictates that the trees of the Rowland Ranch were probably used as the original stock for the "Cave Ranche" (Unrau personal communication).

Concurrent with planting historic saplings in the Park orchard, other saplings of the same genetic stock will be planted and maintained at the Baker Ranger Station and at Capitol Reef National Park. By spatially separating trees of the same genetic composition, we will minimize the chances that a localized disease or insect infestation will compromise these genetic resources. Grafts from these trees will be available to replace the older trees of the Orchard when necessary, and thus perpetuate the historic genetic resource.

From early photographs (Figures 5 and 6) and maps (Figures 3 and 4) of the Lehman Orchard area, it appears that the original orchard included about 7 acres and extended further east to a point in line with the Lehman pond and was surrounded by a fence, presumably to exclude livestock. We will not try to plant trees throughout the entire 7 acre area. Given the Park's restricted water rights, the new plantings will require a drip irrigation system in lieu of the flood irrigation system historically used. A smaller area is desired for a drip irrigation system. New trees will be planted as close to historic locations as possible. At least 13 saplings will be planted in exact locations of the historic trees as shown on the 1938 map. An additional 15-20 saplings will be planted among and adjacent to the historic locations making a total of 35-40 trees. This number approximates the size of the original orchard.

It is desired that the planting arrangement mimic the historic patterns of the orchard. From the few early photographs and maps of the orchard, it appears that the trees were not situated in rows as commonly done today, but randomly located throughout the orchard. There is no evidence that trees of the same species were historically clustered together. When planting, we will mingle varieties, attempting to maintain the full compliment of historic types. Each new tree will be surrounded by a wire basket supported by upright posts to protect the trees from deer herbivory.

Initial planting and replacement of stock is dependent on individual varieties and will depend on the requirements of replacement stock. The following guidelines should be followed when planting.

Apricots, Plums and Peaches In cool climates, apricot and peach trees are planted while the trees are still dormant in the late winter or early spring. Before planting, roots should be temporarily kept moist in peat moss, old straw, or sawdust. If planting is delayed, seedlings can be placed in well-drained, moist soil. The hole for each seedling should be deep enough that roots are not bent. The soil should be thoroughly plowed or spaded just before planting to loosen the soil and remove weeds. The soil should be firmly packed around the seedlings and watering should commence shortly after planting. Nitrogen fertilizer, one-eighth to one-fourth pound per inch of trunk diameter, should be spread evenly over a three-foot circle around the tree at planting. This should be repeated in the early summer if soil is deficient, but not again after mid-summer.

Apples, Crabapples and Pears In most cases avoid fall planting because of the risk of frost-damage to seedlings. When planting in the spring, plant as soon as the soil is dry enough to spade. Prior to planting, the seedlings should be unwrapped and the roots kept moist and above freezing. The seedlings should be planted while still dormant or at least before much root growth has occurred. The hole dug for each seedling should be deep enough that the roots are not bent. The trees should be watered immediately after planting, but no fertilizer should be applied until after the first summer unless highly buffered varieties are used.

LC346- Looking towards the developed area from the East. The entrance road from Ely is shown on the left.

Figure 5. Photograph of the Lehman Orchard Looking West

LC347- Looking east from the Monument over Snake Valley. The cultivated land shown in the distance on the right is the Baker Ranch. "The Covered Wagon" was filmed on and near this ranch.

Figure 6. Photograph of the Lehman Orchard Looking East

Non-Historic Trees There are a number of trees that were planted in historic locations or in proximity to the Lehman Orchard by local school children as part of a bicentennial celebration at the Park (Figure 7). They are not historic varieties. Non historic trees that are in historic locations will be replaced by historic varieties. As historic varieties are planted and successfully established, non-historic trees that are in close proximity to the historic orchard will be removed. Those that are clearly ornamental (located in the parking lot medians) may be allowed to remain at the Superintendent's discretion for aesthetic purposes but will not be replaced when they die.

MANAGEMENT ACTIONS: ORCHARD PROCEDURES.

Pruning

Trees are solar collectors. Collection is dependent upon the tree's shape. Greatest efficiency is achieved when each branch, from top to bottom, is allowed to receive maximum sunlight. Removal of branches which are either too close, growing inward toward the trunk or vertically up or down is necessary.

The tools required are simple: Corona "80" pruning shears, long handled lopping shears, pole saw with extensions, and stepladders. Pruning tools must be kept razor sharp, since frayed cuts are of no benefit to the tree. Normally, cutting tools will need to be sharpened and/or adjusted at least once a day.

In pruning historic trees, careful technique is essential. Ropes cannot be used, as they will damage the bark. The same is true for D-belts, climbing spurs, or ladders placed against the trees. The trees must be free-climbed, using uncleated soft-soled shoes. Flat-footed contact with the branches should minimize bark damage. Weight distributing posture should be employed to avoid broken branches.

The principal cut used should be the "target" cut. All branches, regardless of size, arise from buds. In target cutting, this budding structure is left intact, allowing rapid healing. It is never appropriate to leave a stub beyond the budding structure. The flush cut, another type, is used only in removing branches thicker than 1.5 inches from the top side of horizontal branches (the budding structure is then removed to prevent water pooling). Although there is no benefit in using tree sealer on cuts, large cuts may be aesthetically enhanced with black or brown spraypaint.

All branches should end in a doublet, or fork. Apricot trees have a natural tendency to form triplets, so this third branch requires removal. There should be no branches growing straight up or down, as these will ruin the "tiered" or "layered" effect. Successively higher tiers are formed by scaffold (main) branches, arising at approximately 60 degree angles from the branches of the underlying tier. Each tier's outreaching branches are horizontally staggered, so as to avoid shading the branches in the tier below. It is important to have adequate vertical clearance between successive tiers.

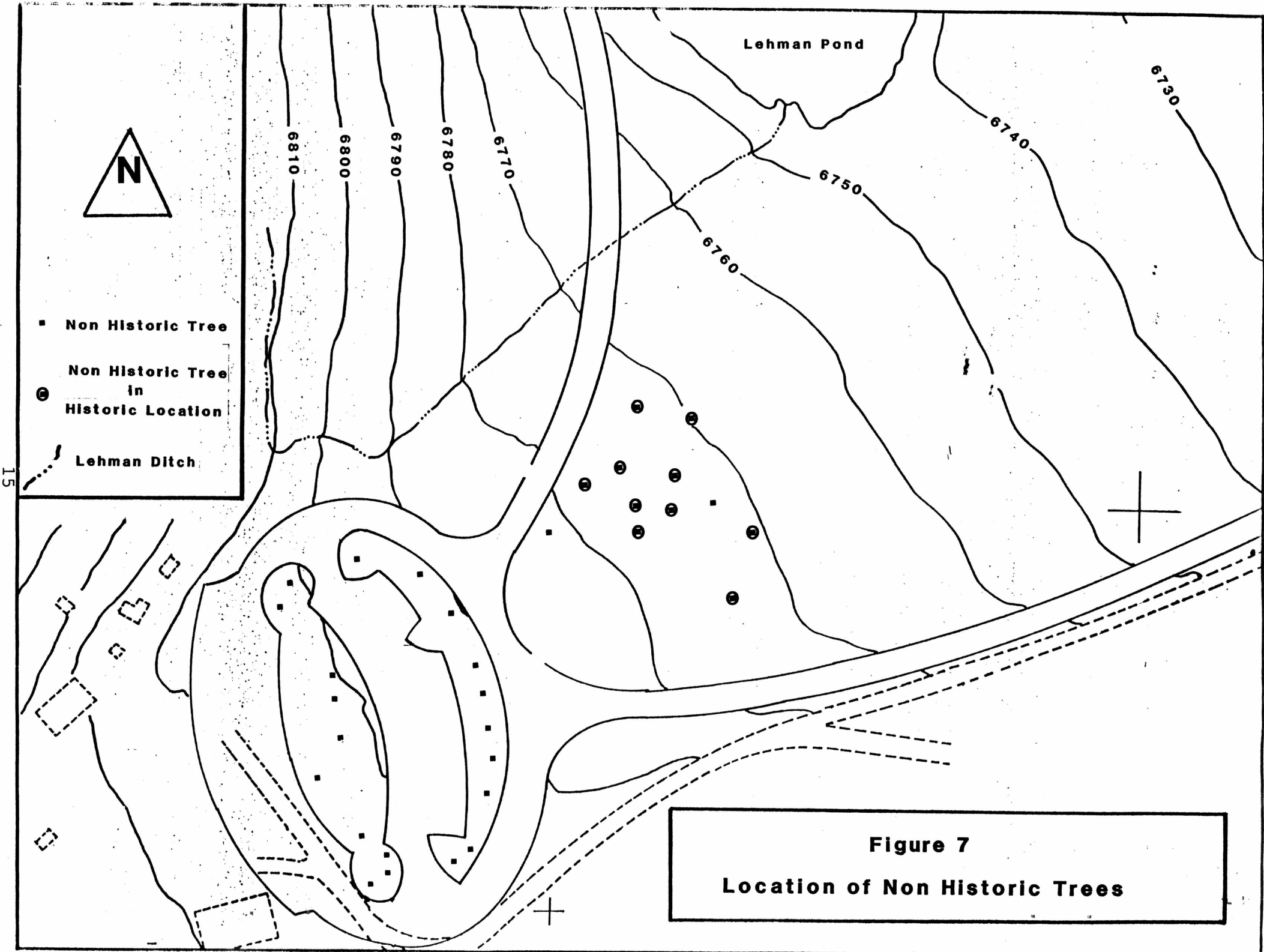


Figure 7

Location of Non Historic Trees

The mass of tree below ground closely approximates the visible tree. Severe pruning thus creates an imbalance which should result in vigorous growth. Often the tree will produce whip-like, fast growing vertical watersprouts. Some of these may be cultivated to form future branches. The rest should be removed during the growing season so the tree may direct its growth potential elsewhere. Severe pruning should be utilized only every other year. Light end pruning, removal of dead and/or deer damaged limbs and elimination of undesirable watersprouts is recommended in intervening years. All cut wood should be removed, to prevent the spread of disease or insects.

Major pruning should be accomplished between the time of leaf fall and bud swelling. Trauma is minimized during this period of dormancy, provided the trees are not climbed when frozen. Although bud swelling typically occurs in early April, variations of a month or more occur. Mild winters tend to favor an early bloom and result in a loss of crop to frost.

Longevity, rather than crop production, is of primary importance in caring for historic trees. Aesthetics are also of great importance. It is necessary to tolerate many "wrong" major branches in the trees. Patient cultivation of future replacement branches is the only acceptable method of correction.

The appearance of the trees should be checked from many vantage points, to ensure a "balanced" look on both an individual and collective basis. The ground slope and relative size of the trees must be considered in making the trees appear to have a uniform "mushroom" shape.

Apricots, Plums and Peaches There are several stages of pruning for apricot and peach trees. At planting time the top of the main stem should be pruned 18 to 30 inches from the ground. Lateral branches within one foot of the ground should be cut back close to the trunk; large lateral branches attached higher on the trunk should be cut back 4 to 6 inches in length. Ideally, the shape of a young tree should be controlled by 3 to 4 major branches (scaffolds) coming from the trunk, and well spaced around the tree, shaped to an open, or "vase" pattern. Laterals forming on the scaffolds near the trunk should be removed, but others should be allowed to grow.

Since most apricot trees bear the majority of their fruit on the spurs, which are short-lived, about one-third of the spurs should be pruned each year. Pruning should be done to encourage spacing of branches for better sunlight exposure and thinning of upper branches to prevent excess shading.

Apples, Crabapples and Pears Pruning of apple trees should be done in late winter or early spring. Young apple trees should be pruned sparingly. Pruning cuts should be made flush with the main limb without leaving stubs. For young trees, all branches lower than 20 inches on the trunk should be removed. In addition, all dead and broken branches should be removed each year. During the first two years, lateral branches should be spaced at equal intervals along the main stem. The ideal for mature or maturing apple trees is a central leader which is taller than the other side branches. A 5 year old tree should have 5 to 7 radially arranged side branches well spaced around the central main trunk. As the tree matures, it may be periodically necessary to remove some of the high central branches to prevent the tree from growing

too high. Pears generally grow strictly upright and do not branch freely. The multi-leader is the common training method. The fruit is borne on spurs or terminally on longer spurs. The young trees should be pruned annually to shape the tree and prevent long, narrow crotches. Mature trees can be pruned every other year, taking care that the top does not overgrow and shade out the lower limbs.

Wounds and Damages

The use of wound dressings is a long practiced technique once believed to limit heart rot or correct pruning damage. In fact, except for cosmetic purposed, it provides little or no benefit to the tree. Tree wounds often occur because of ice damage or improper pruning. When pruning or removing ice damaged limbs or branches, target cuts should be used, in which the limb is removed flush with its budding structure. A stub should never be left. Normally during pruning, narrow V crotches should be eliminated, thus lessening the chances of branches growing flush with one another and creating conditions of incomplete bark development. Optimal scaffold angles are approximately 60 degrees.

Roots of seedlings are often damaged during planting. This may have serious long-term consequences for the health of the tree. When planting, the hole for each seedling should be wide and deep enough so that the roots are not bent. In addition, fine top soil or a proper planting mix should be used to fill the hole.

Watering

For maximum tree and fruit growth the trees should receive suitable water from pre-bloom through harvest and for a short post-harvest period. Watering frequency is most critical before harvest for maximum fruit size and yield. Post harvest watering favors good flower bud development the following spring and, in part, hardens the tree for winter by stimulating late-season carbohydrate production and storage.

The subsoil of the Lehman Orchard is a fine-sandy loam to sandy loam in texture. For such soils the soil moisture levels should be a minimum of 45% for most fruit trees during the growing season. A soil moisture meter with electrode blocks at four different depths in the soil column has been placed in the orchard for measuring moisture levels of the soil. Additional blocks will be placed in the vicinity of newly planted trees. The meter measures the percent of maximum water storage for the soil at each particular depth. Care should be taken to avoid rapid fluctuations in water content above and below the 45% soil moisture level. Severe moisture stress from one to one and one-half months before fruit harvest will usually cause much of the fruit to fall. Curled, dried or yellowish leaves are additional signs of advanced moisture stress on fruit trees.

During the summer of 1984, a series of experiments were performed to better understand the water storage behavior of the soil in the Lehman Orchard. The soil moisture saturation percentage was measured five to six days per week.

Soil moisture percentages were then plotted as a function of rainfall, duration of orchard irrigation and daily high temperature.

The soil in the orchard seems to retain moisture the longest after four to six days of consecutive high volume, long duration watering. Water should remain on both day and night. After watering, the soil remains adequately moist for at least one week. Moating of tree perimeters at the dripline will help in irrigation. Light continuous watering seems to be less effective, possibly because high evapotranspiration may draw water up through the soil column from deeper levels while keeping surface soil layers wet.

The objective in watering the orchard should not be to keep the soil completely saturated, since historic trees have probably adapted to drier conditions than normally encountered by modern varieties of fruit trees. Continuously saturated soil conditions may, in fact, stress the trees by not encouraging root expansion. Rather, soil moisture levels should be kept near 45% as consistently as possible, including the early fall after the fruit has fallen.

Fertilizing

The ground beneath the trees, to the dripline, should be tilled annually in the spring. Mulch or compost should be added at this time as well. If soil analyses indicates nutrient deficiency (nitrogen) a commercial fertilizer should be applied. A dichondra fertilizer, Bandini Super Green, is a proven way of enhancing the nitrogen content of the sandy loam soil without "burning" the tree roots (as harsh, unbuffered high nitrogen fertilizers will). Recommended application is 1/4 pound per inch of trunk diameter, three weeks prior to bloom, every other year. Weeds and grasses should not be allowed to grow immediately beneath the trees, as they compete for water and nutrients. Hoeing, plus the use of lawn clippings and leaves as a ground cover, provides an effective means of control. Ground cover has the additional benefit of reducing evapotranspiration.

Apricots, Plumbs and Peaches Apricot, plum and peach trees are often deficient in nitrogen. Signs of low nitrogen levels may include yellow foliage, smaller, firmer fruit, and fruit that matures too early. Usually, one-quarter to one-pound ammonium nitrate, or equivalent, per tree per year is adequate. It may be applied after July during the growing season, or within 3 weeks before blooming.

In some cases, apricots may need additional potash, as determined through ongoing soil analyses. In such cases, 2 to 4 pounds of muriate or potash sulfate for each mature tree is necessary.

Apples, Crabapples and Pears Apple trees should be fertilized about two weeks before bloom in the spring; fertilizer should never be applied in mid-to late summer. Like apricots, apples usually are most in need of additional nitrogen. Ammonium nitrate at one-quarter pound per tree multiplied by the number of years the tree has been set (but not to exceed two and one-half pounds per tree) is applied to moderately fertile soils. Signs of low soil

nitrogen levels include pale green or yellowish leaves in the summer and short shoot growth. Low soil nitrogen should be confirmed by soil analyses. Fertilizing should be delayed until the following spring even if trees exhibit these signs of nitrogen deficiency during the summer.

Pears may be fertilized like apples except that after the appearance of fireblight, pears should be fertilized sparingly since the young growth spurred by fertilization is more subject to fireblight infection.

Pest Management

There are numerous pests and diseases that may present problems in managing the Lehman Orchard. It is the policy of the National Park Service to use integrated pest management (IPM) principals and evaluate all possible options for pest management including changes in cultural practices, mechanical control methods, biological controls and if necessary, chemical control (U.S. Dept. of Interior 1988).

Table I shows the most common insect pests and diseases infesting apricot, peach, apple and pear trees.

Table I
Common Insect Pests and Diseases to Fruit Trees

	Affected Fruit			
Pest/Disease	apricot	apple	peach	pear
Aphids	x	x	x	
Borers	x		x	
Grasshoppers	x		x	
Japanese Beetles	x		x	
Mites	x	x	x	
Oriental fruit moth	x		x	
Plum curculio	x		x	
Scales	x	x	x	
Leafhoppers		x		
Codling moths		x		x
Tent caterpillars		x		
Brown rot	x			
Shot hole (Coryneum blight)	x			
Bacterial canker	x			
Cytosporina	x			
Crown gall	x			
Powdery mildew		x		
Fire Blight		x		
Pear Rust Mite				x

Several vertebrates also impact the orchard trees. Deer are a significant source of herbivory, and if trees are not protected will quickly destroy young trees. Rodents also chew on the bark of young trees and will girdle and kill young trees if protective measures are not taken. Sapsuckers drill into the bark of older trees making them more susceptible to insect infestation and disease.

Monitoring is the key to a successful IPM program. By carefully monitoring the presence of pest species, appropriate action can be taken in a timely manner to effectively solve pest problems. Too often proper monitoring is not carried out and pests are not detected until they are well established. At this point, blind attempts are usually made to solve the problem with a non-specific chemical program. Such programs are against National Park Service policy and usually cause more problems than they relieve. The incorrect application of chemicals can result in a secondary infestation by eliminating a beneficial predator, thus escalating a minor problem to a major one. The effective application of any pest management scheme requires accurate timing. Proper monitoring techniques provide identification of pest problems at an early stage of development. Once detected, the pest problem can be evaluated and an action level set.

The following methods have been used successfully to monitor for different insect pests (NPS 1984):

1. Sticky traps for various insect pests
2. Pheromone traps for coddling moth and peach borer
3. Vacuum collection
4. Tanglefoot for crawling insects
5. Visual observation
6. Quadrat monitoring
7. Pitfall traps

To date, the Lehman Orchard has been relatively insect pest free (Stewart Vaughn personal communication). The goal of our orchard management program is to encourage healthy plants that are resistant to disease and pest problems. Our orchard management practices will center on alleviating stress in the plants leading to increased pest resistance. Since production of commercial quality fruit is not a management goal of the Lehman Orchard, we will surrender a fruit crop rather than use potentially dangerous chemicals to control insect pests. The protection of the trees is paramount and methods to control insect pests may include chemical treatments.

In conversations with local orchard owners and past Lehaman Orchard caretakers, the pests that present a likelihood of becoming a problem in the Lehman Orchard are Peach Borers, Shot Hole Borers, and Coddling Moths. Shot Hole Borers may be adequately monitored by visual inspection. Coddling Moths and Peach Borers will be monitored by pheromone traps set out in the Orchard. If they are detected in the orchard, specific IPM plans will be developed to address each species of concern.

Currently, the only serious pest problems that exist in the Lehman Orchard center on vertebrates. Young trees may be damaged by animals such as meadow

mice, rabbits and hares, and deer. If the bark is chewed completely around the trunk the tree will die, unless it is bridge grafted. Tankage, a pulverized animal slaughter by-product, in a small cloth bag hung in the tree, can sometimes repel deer. Crushed stone or mothballs (paradichlorobenze), packed around the base of the trunk, and one quarter inch mesh screen wire guards, about one to two feet tall, wrapped several times around the trunk, can discourage rodents. Initially, we will employ barrier fencing and trunk guards to deal with these species. These will not require the development of an IPM plan.

Cultural practices, mechanical operations, and biological controls will be employed in lieu of chemical controls whenever possible. If the application of pesticides becomes necessary, spot treatments are encouraged rather than a broad based action. Appendix A contains IPM procedures for most of the possible pests outlined in Table I. These procedures, obtained from the NPS IPM Handbook and the John Muir National Historic Site Orchard Management Plan, outline the methods to explore in dealing with individual pest species. The procedures will be tailored to the situations found in the Lehman Orchard as the need arises. Future IPM plans developed for the Lehman Orchard will be appendicized to this plan.

Disposition of Fruit.

Although the production of fruit is not the primary goal of the orchard's management, these trees do produce high quality fruit. The small quantity and the high likelihood of damage to trees prevents the Park from offering the fruit to all willing harvesters. Removal of fruit should be restricted to distribution during interpretive programs or to small quantities gathered by the public without the use of ladders or other tools for personal consumption at the site.

MANAGEMENT ACTIONS: RECORD KEEPING

Accurate record keeping is essential to the proper management and preservation of historic trees. Historic orchards are distinct from commercial orchards in that each individual tree is the resource of concern. Production of fruit is secondary to preservation and perpetuation of the genetic resources of each individual tree. Each tree must be permanently identified and a chronology of care recorded. Without proper records the genetic significance of replacement progeny cannot be maintained. Records are also necessary to ensure proper maintenance procedures are followed and IPM systems are monitored to detect pests.

To assure that the genetic identity is maintained and a record of care and treatment is maintained, each tree will be assigned and tagged with a permanent number that it will carry until its death at which time the number is retired. Trees at the historic orchard and at the Baker Ranger Station will be mapped with the location of each tree recorded and entered into the Park GIS. Trees kept at Capitol Reef National Park will be tagged with a permanent number, entered in a computerized database and mapped. Each tree in

the historic orchard and at the Baker Ranger Station will be examined on a weekly basis and a field log kept as to the date and maintenance action taken (pruning, watering, etc.) (See Appendix B for sample field log sheet). The weekly field log will be returned to the Resource Management Specialist and data on individual trees entered into a computerized database (See Appendix C for database structure). In addition, any chemical treatment for pests or disease at the historic orchard or the Baker Ranger Station will require prior approval and recording on a pesticide use log (Appendix D).

ORCHARD MANAGEMENT RESPONSIBILITIES

Resource Management Specialist

Writes and updates Orchard Management Plan and associated cultural and environmental compliance documents.

Acts as the IPM Coordinator of the Park and writes, as necessary, the Orchard Integrated Pest Management Plans and coordinates treatments with maintenance staff. Obtains permission for use of chemical treatments through submittal of 10-21A and submits annual pesticide use report to region.

Maintains computerized database on individual trees. Coordinates research on historic trees and contracts, as necessary, to propagate historic replacement stock.

Buildings and Utilities Foreman

Responsible for the construction of barrier fencing and planting of new orchard stock in coordination with the Resource Management Specialist.

Follows the Orchard Management Plan to implement orchard management procedures assuring proper maintenance of historic orchard trees at Lehaman Caves and the Baker Ranger Station.

Assures that weekly field data sheets and if necessary, pesticide use logs, are completed and forwarded to the Resource Management Specialist.

Maintains Orchard Management tools and equipment.

Interpretive Specialist

Promotes the historic Lehman Orchard as an element in the Park Interpretive Prospectus.

Develops programs, wayside exhibits and newspaper articles to interpret the significant genetic and historic resources of the Lehman Orchard.

Visitor Protection Specialist.

Assures that visitor use and removal of fruit from the historic orchard complies with the Orchard Management Plan and 36 CFR.

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Appendix A

Sample IPM Plans

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

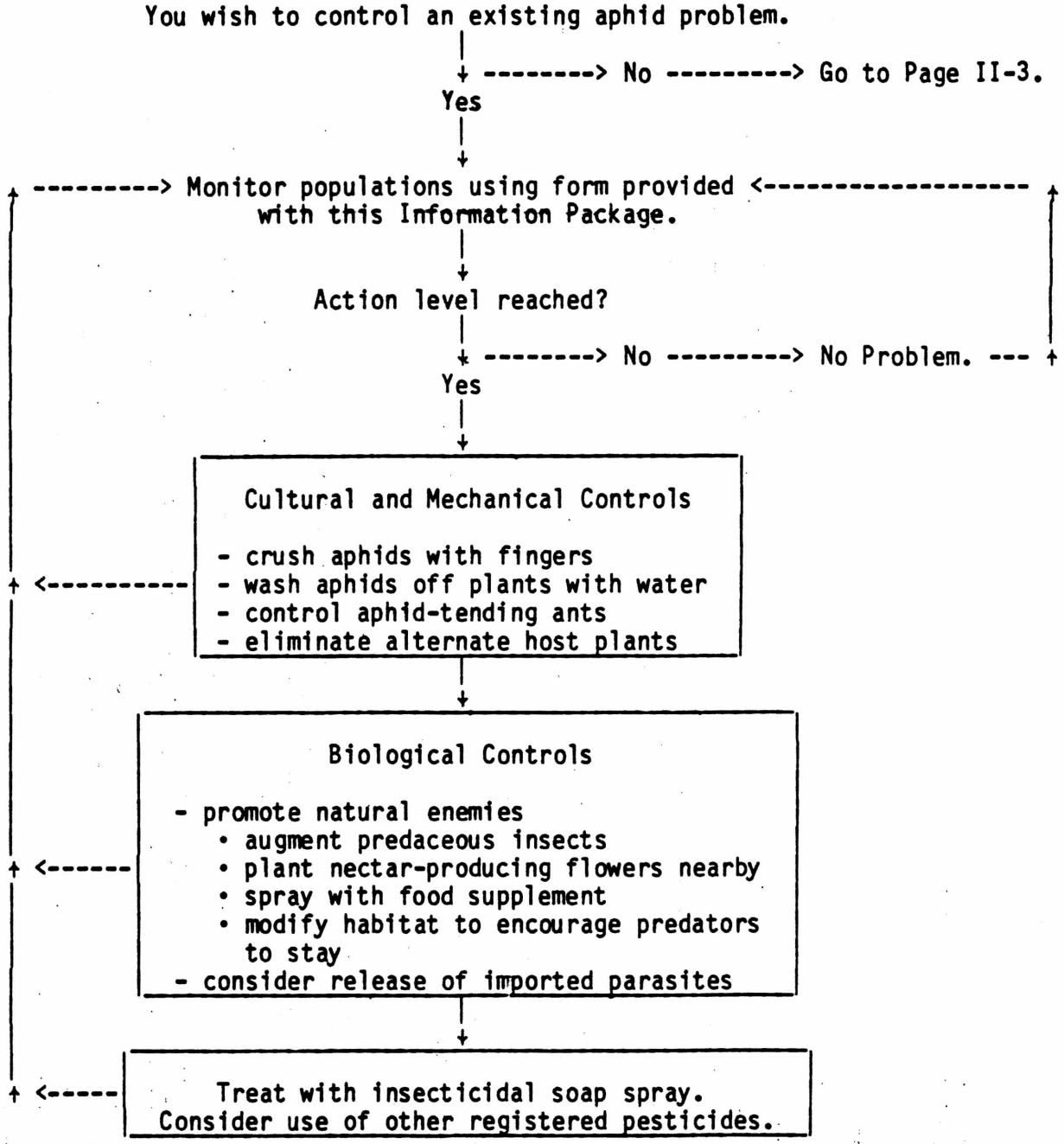
Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

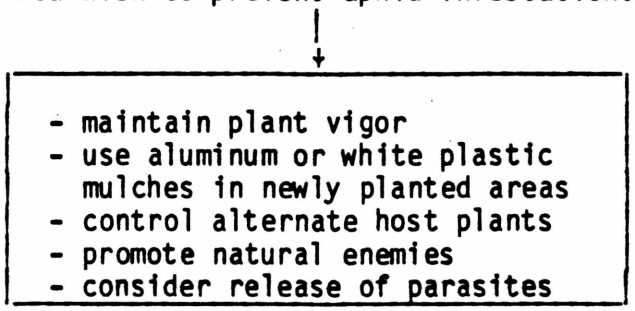
CONTENTS

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, many 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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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

CRICKETS AND GRASSHOPPERS

Final Report

1 December 1984

Submitted To:

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

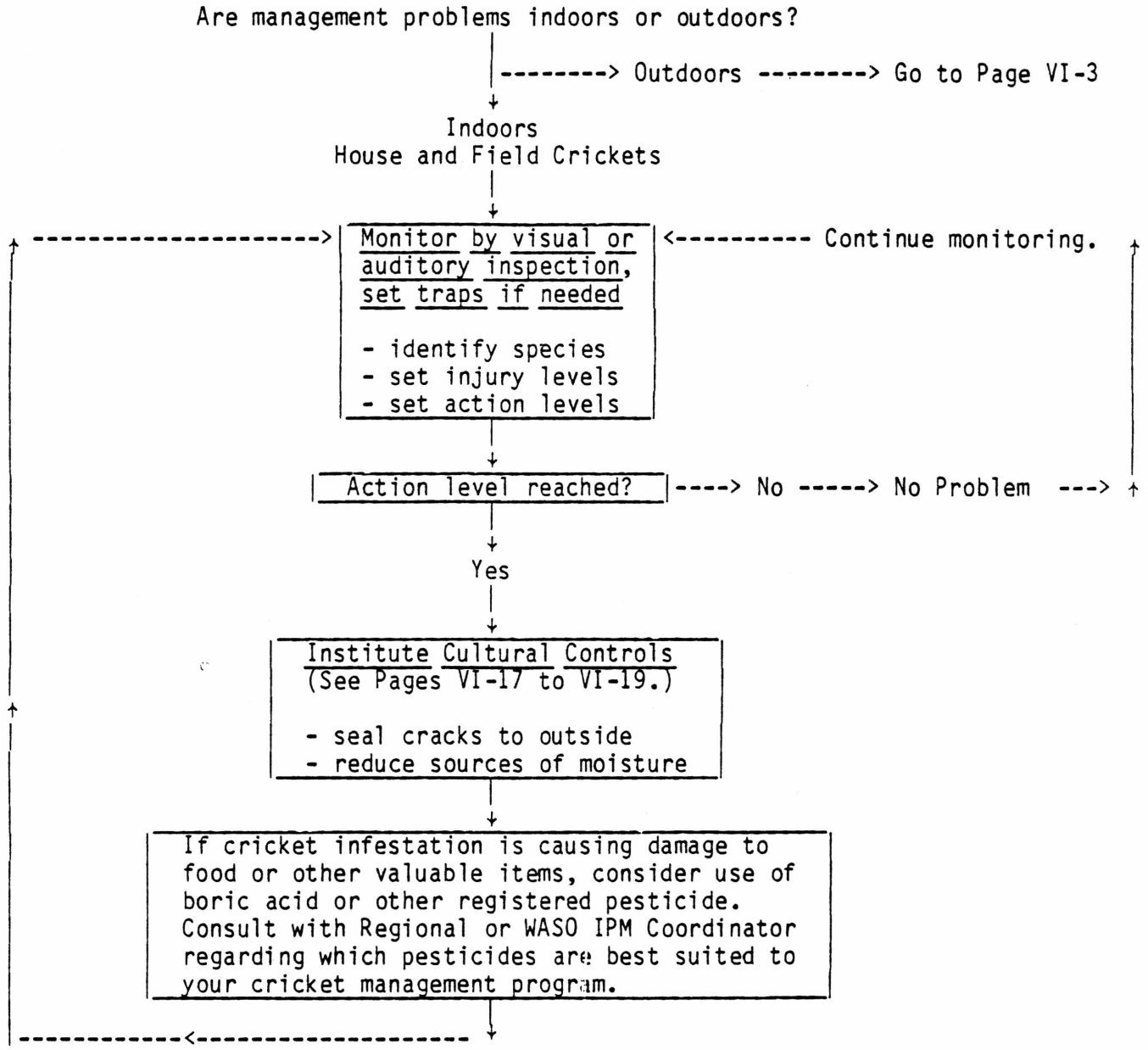
Submitted By:

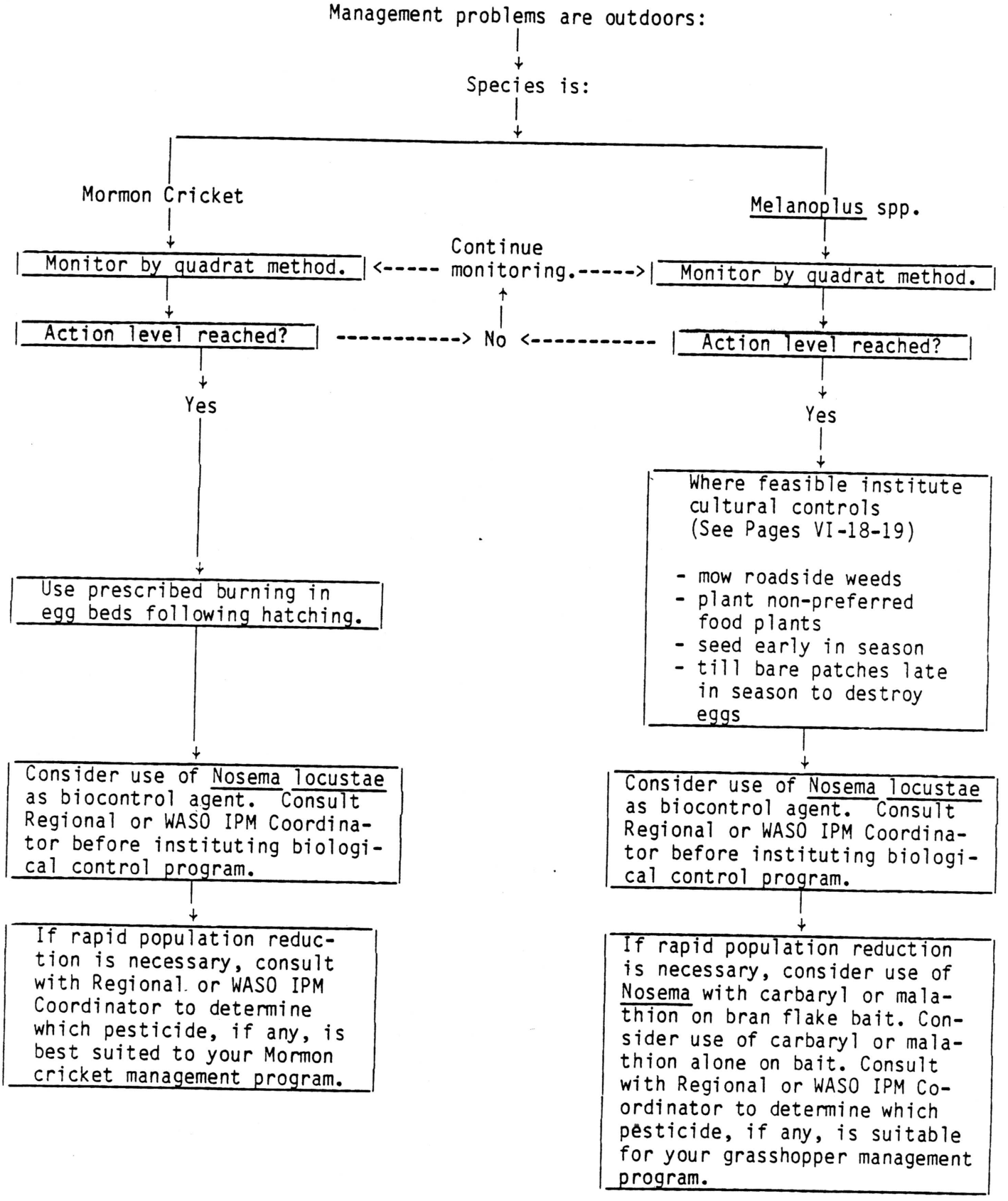
Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

CONTENTS

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
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
Use prescribed burning in egg beds following hatching.
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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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															
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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

MITES

Final Report

10 July 1984

Submitted To:

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

Submitted By:

Dynamac Corporation
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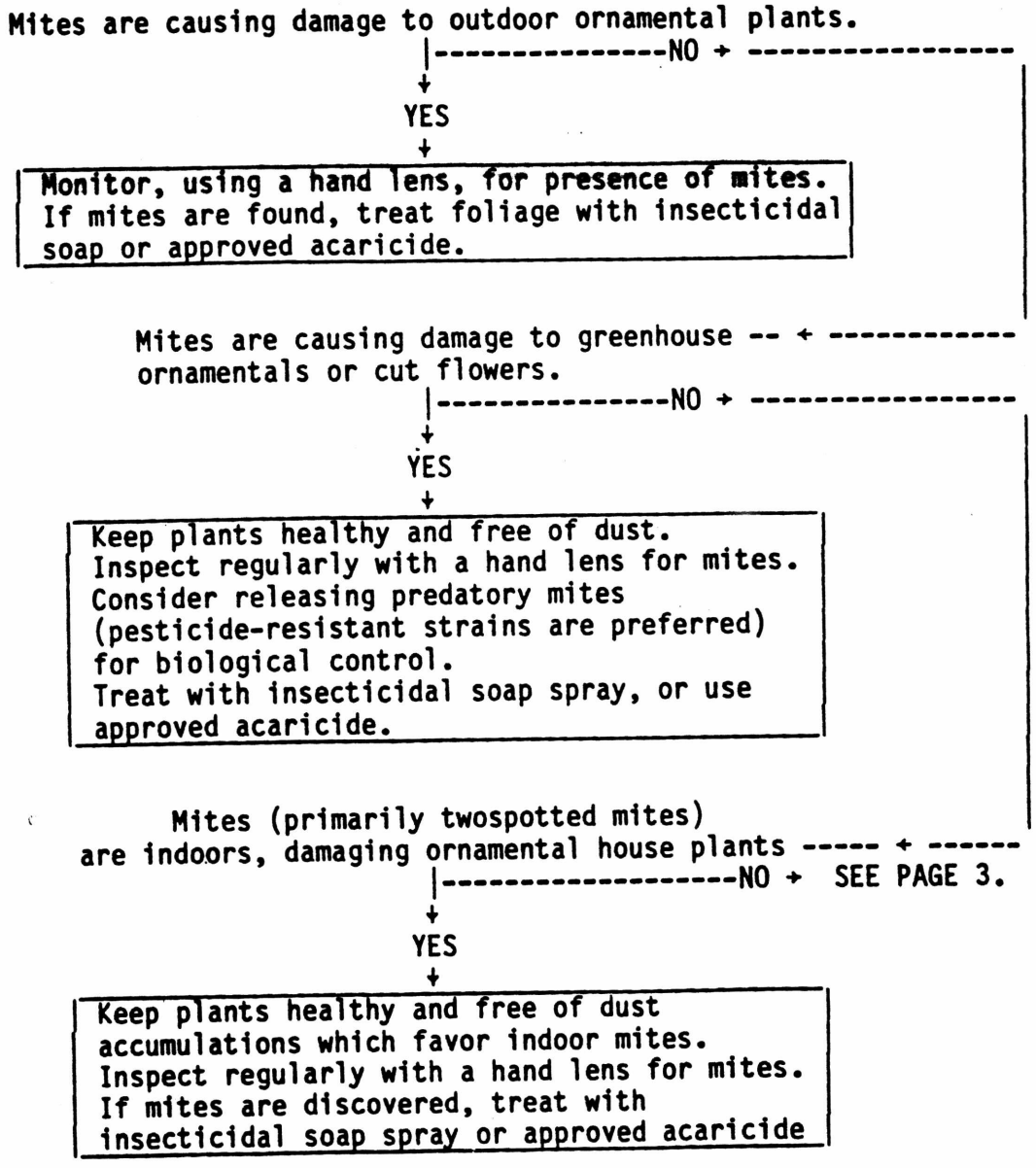
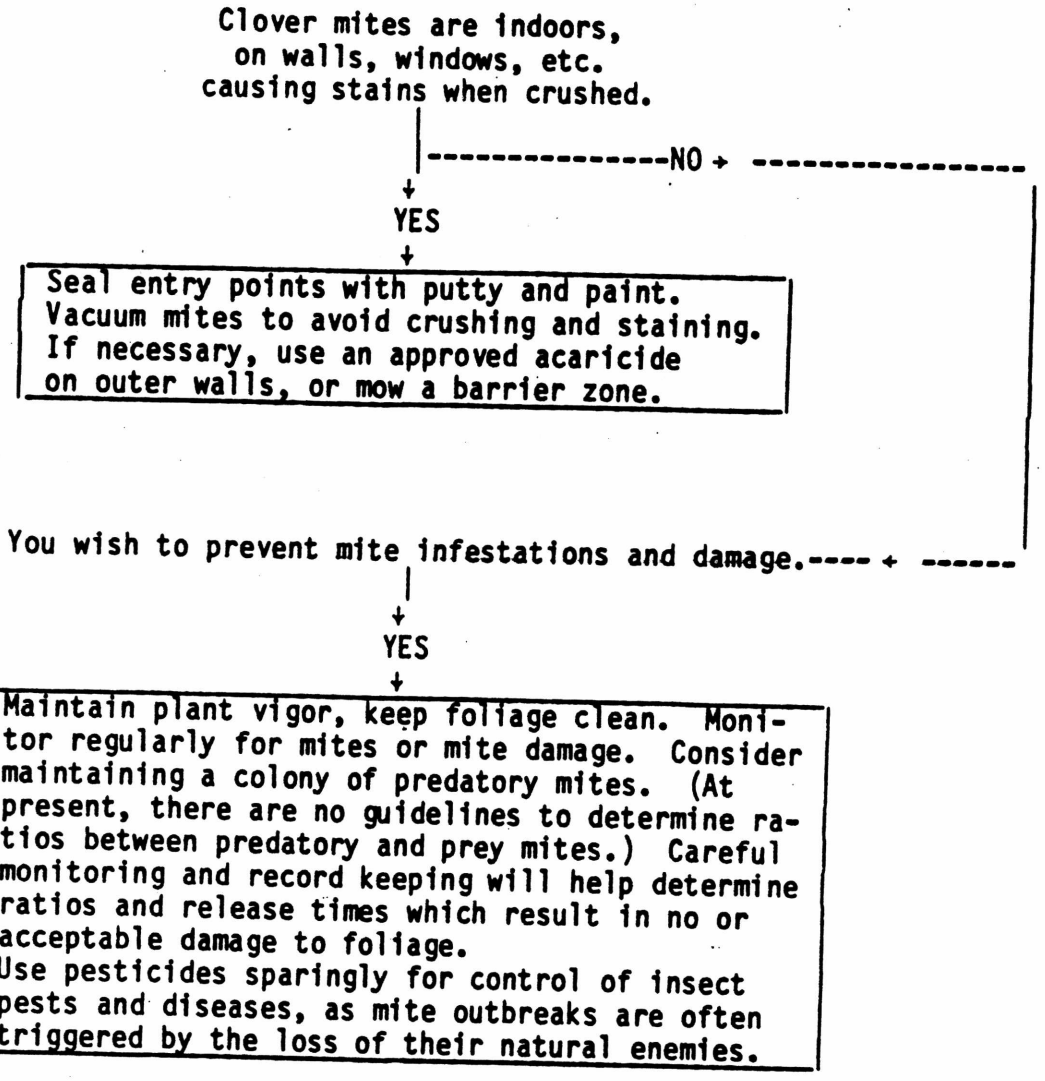
CONTENTS

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. <u>Seasonal Abundance:</u>

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 supplyiment 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

SCALE INSECTS

Final Report

15 April 1984

Submitted To:

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Washington, D.C. 20240

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CONTENTS

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.

→ No → (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.)

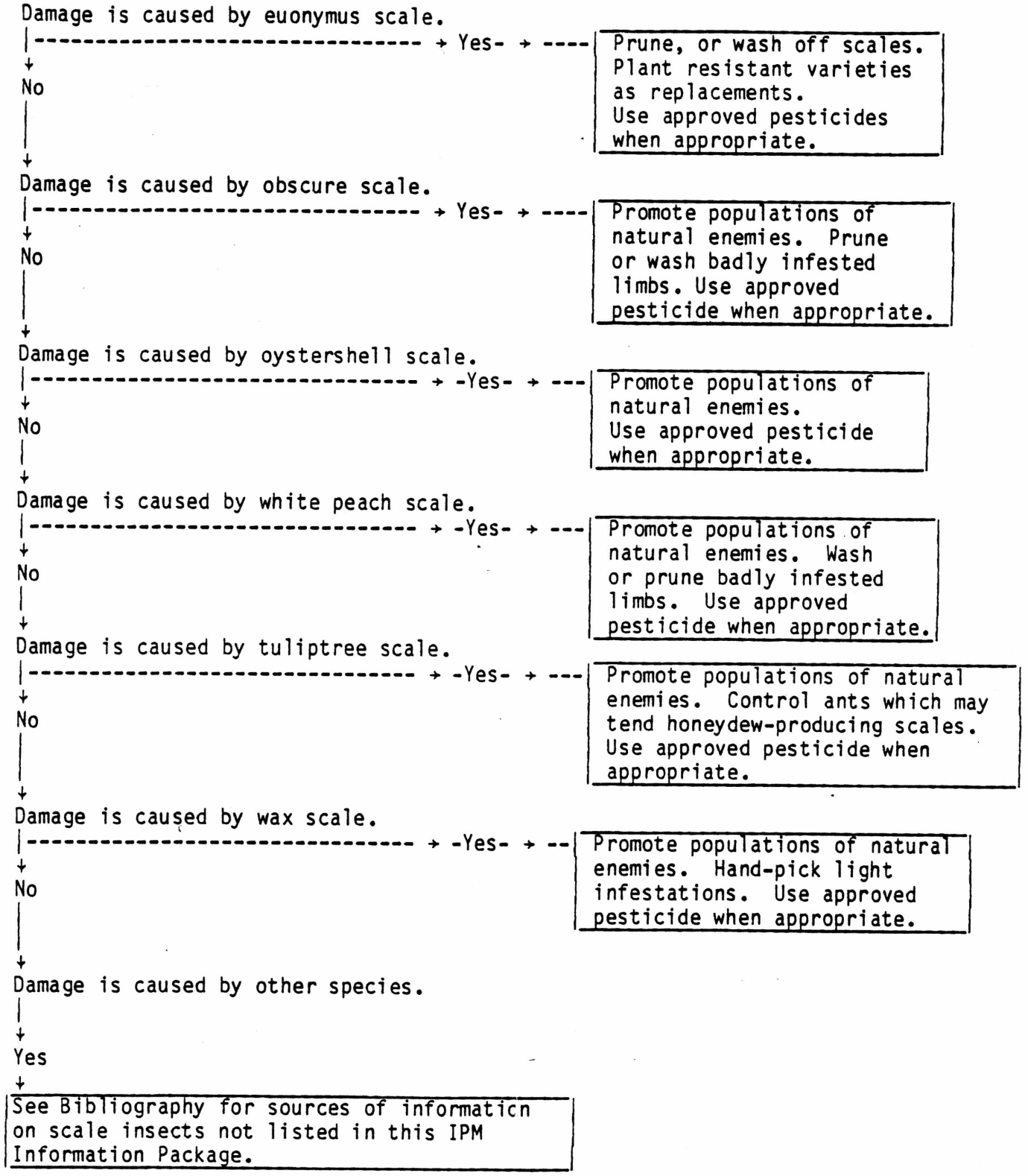
Yes

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 mouth-parts. 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

TENT CATERPILLARS

Final Report

February 1984

Submitted To:

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

Submitted By:

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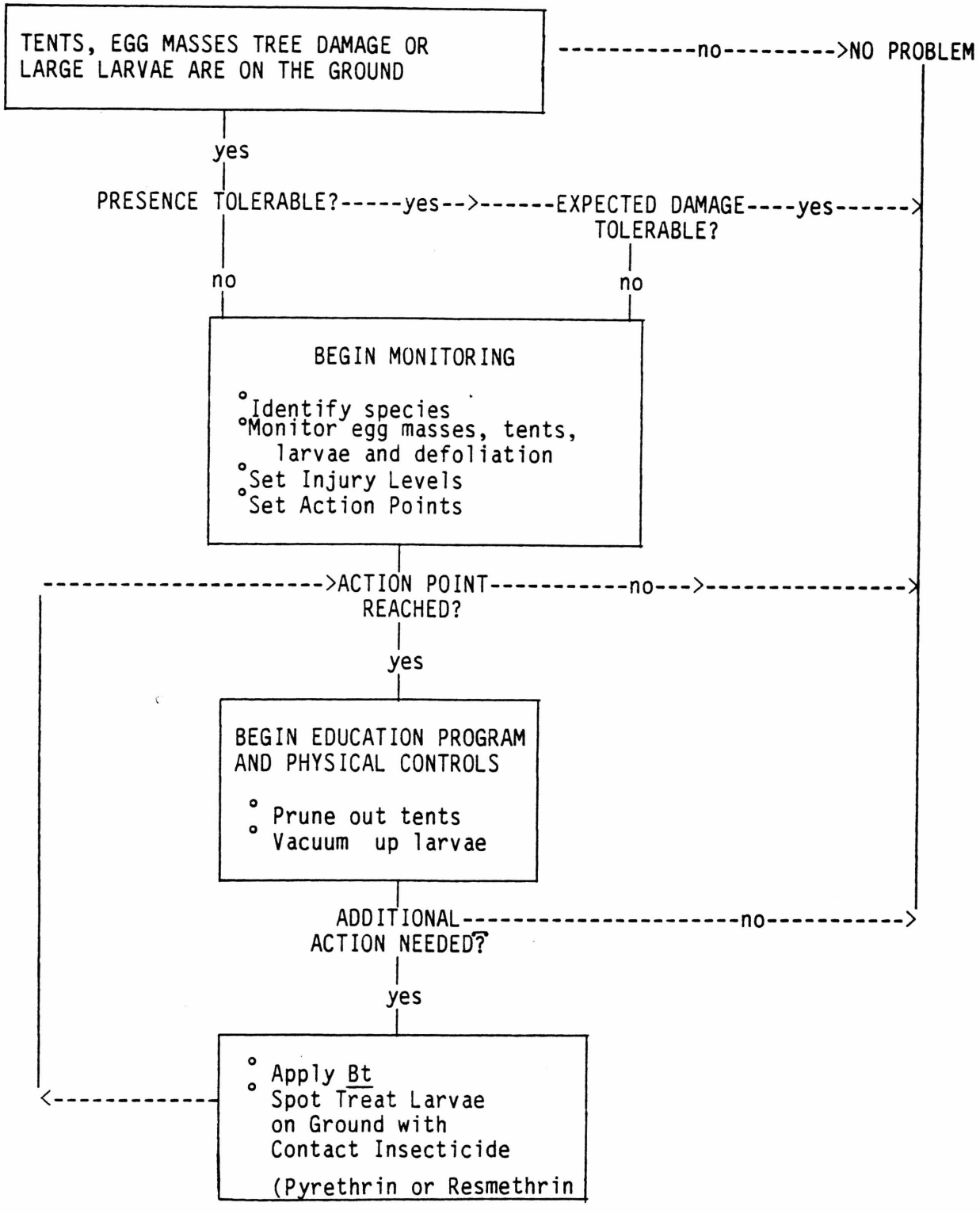
CONTENTS

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)	DIAMETER AT BREAST HEIGHT (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

BLACKSPOT AND POWDERY MILDEW

Final Report

30 September 1984

Submitted To:

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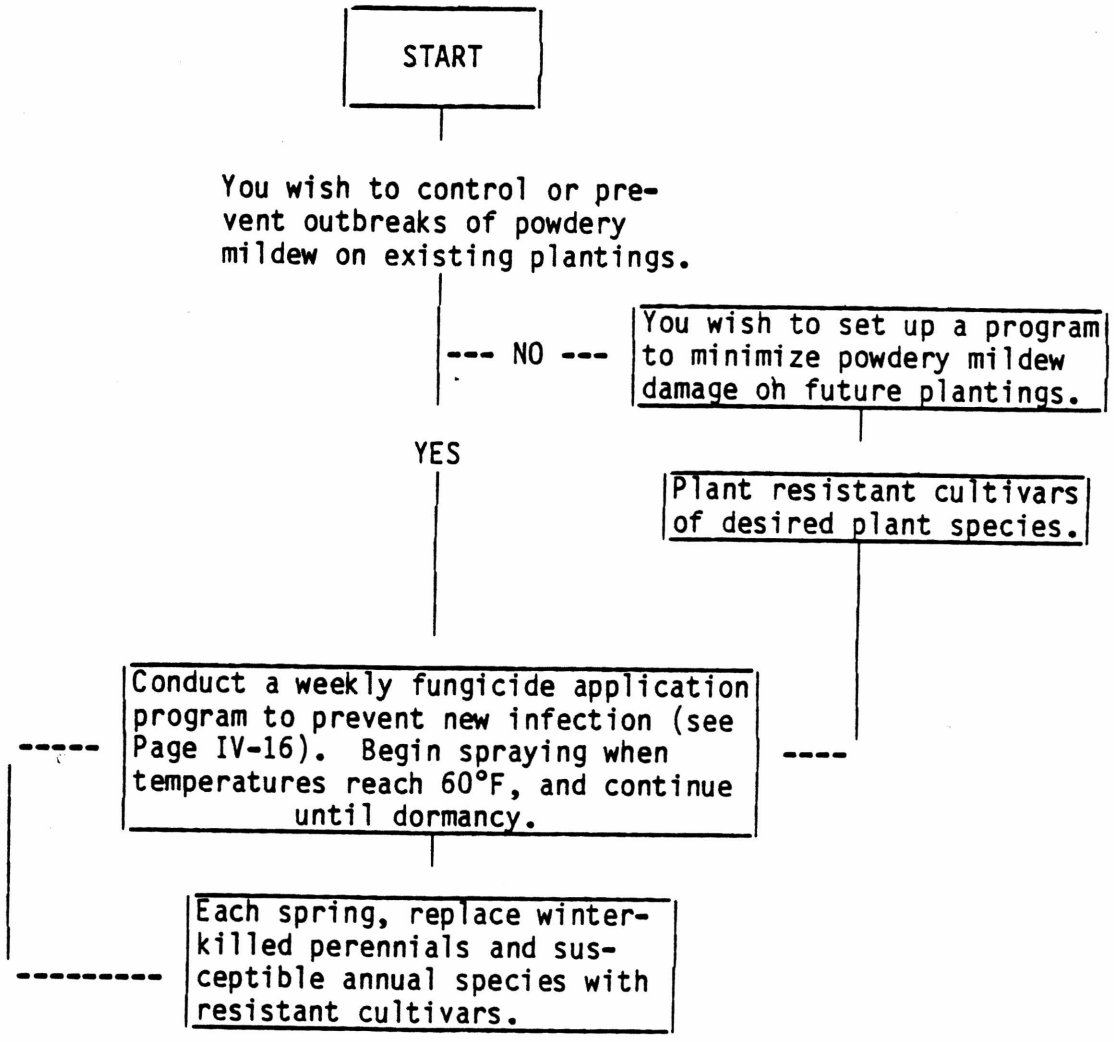
V. POWDERY MILDEW IPM DECISION TREE

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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INSECT PROBLEMS AND SOLUTIONS

Coddling Moth (Laspeyresia pomonella)

Description - there are four stages:

1. the eggs are about the size of a pinhead.
2. pupae are yellow to brown ½ inch long.
3. larvae are whitish with dark heads 3/4 inches long.
4. adults have brownish front wings, wavy cross lines, and a characteristic copper spot near the tip of each wing, wing span 3/4".

Life cycle: Pupae emerge in the spring when fruit trees are in bloom. Most activity is during sunset. A moth can lay fifty to seventy-five eggs on fruit, twigs, and leaves. Eggs hatch into larvae which enter the fruit, feed for several weeks and emerge to pupate leaving behind a characteristic brown frass. After pupating in hidden places (crotches, wounds, bark) they emerge as adults. There are several generations and depending on temperature, eggs hatch in 5-12 days. Larvae feed for 25-35 days and pupate for 8-20 days. Moths do not lay eggs below 65 degrees F and will not fly below 55 degrees F.

Control

1. Trichogramma wasps will be released when the monitoring indicates the first generation has begun to mature.
2. Place a sheet around the tree and eliminate all loose bark which can serve as egg laying sites during dormant season, remove all loose objects under trees (firewood etc.), seal all pruning wounds.
3. Band all trees by late April. Wrap the tree with a 6" wide strip of burlap or corrugated cardboard several times. The flutes of the cardboard msut be at least 3/16" side. Remove the band 1/week in warm weather and 1/every 2 weeks in cool weather. Drop the larvae in gasoline.
4. Remove infested fruit in a plastic bag and place in the sun for two weeks.
5. Thin the fruit when they are ping pong ball size.

Optional

A. Place one pheremone trap in every apple tree.

B. Spread B.T. when the larval stage is detected.

Western Peach Tree Borer (Sanninoidea exitosa graefi)

Description -

This clear winged moth belongs to the family sesiidae, but resembles a wasp. They have a black or metallic blue body color. They appear in this area in May, reach a population peak in July, and persist until September. Females deposit hundreds of eggs on the lower trunk of host trees;

Life cycle: Larvae hatch 2-4 weeks after eggs are deposited. They are cream-colored to white with a brown head. They tunnel through the bark into the xylem and the phloem and can girdle the tree. The pupation takes place in cells constructed of chewed plant materials and frass. This occurs outside the tree in the soil. They overwinter in this stage and emerge as adults the following spring. There is one generation per year.

Symptoms:

1. exudations of frass and sap from tunnels
2. decline of tree vigor

Control:

1. Dig out larvae with a screwdriver or probe hole with a wire.
2. Apply PDB (paradichlorobenzene) in late August before the rains. Apply PDB 3 inches from the trunk in a continuous circular band and cover with 3-4 inches of soil. Do not wet soil or irrigate for 2 weeks after an application. Several weeks later remove the mounded soil to prevent crown rot. This is most effective on borers that attack above the soil level. This will be our last choice and we have not felt the need for this procedure to date.

Mealybugs (Planococcus citri and Pseudococcus longispinus)

Control:

1. predators (ladybird beetles and lacewings)
2. washing with a hose

Aphids Members of the Homoptera. We are concerned with the Green Peach Aphid (Myzus persicae) and the Wooly Aphis Erisoma longerum

Life cycle: Winter is passed in the egg stage, but many generations and rapid reproduction occur beginning in the spring. They are herded by ants for their honeydew excrement. The ants must be controlled simultaneously.

Control:

1. diatamaceous earth sprinkled on the infestation
2. insecticidal soap in spot treatments
3. tanglefoot the trees to prevent repopulation by the ants

Mites/Spider Mites Non-insect Class Arachnida

Description - Reddish brown or pale and resemble miniature spiders

Life cycle: They hide in debris producing many generations a year.

Control:

1. ladybugs, lacewings, predatory mites
2. cold water

Caterpillars (Lepidoptera)

Beside borers and coddling moth, there are a great many lepidoptera of less significance. Some examples are:

- Western tent caterpillar/Malacosoma sp.
- Fall webworm/Hyphantria cunea
- Forest tent caterpillar/Malacosoma disstria
- Fruit tree roller/Archips agyospilus
- Navel orange worm/Amyelois transitella
- Orange Tortrix/Argyrotaenia citrana
- Oriental fruit moth/Grapholithia molesta
- Western tussock moth/Orgyia vetusta

These insects are not expecially significant on the site, but they can cause damage if left unchecked. They are controlled by the following methods:

1. mechanical removal (pruning, and burning)
2. B.T.
3. Trichogramma wasps (if the other methods are not successful)

Pacific Flathead Borer (Chrysobothrismali Horn)

Description:

1. egg - circular flattened pattern 0.04" in diameter
2. larva is whitish and 3/4" in length with a flattened amber colored head
3. pupa is flattened and creamy white, darkening as the emergence of the beetle approaches
4. adult is flattened and up to 7/16" in length, bronze color with coppery spots

Life cycle: There is a single generation a year and the beetles will be present and laying eggs in June and July in cracks and crevices in the bark. The larvae mines directly into the tree, they will remain feeding on the tree and pupate in the fall.

Control:

1. Cultural practices to maintain tree vigor (as outlined in the OMP).
2. Wrap young trees to prevent egg laying.
3. Remove all infested wood from the site and burn if possible.

Shothole Borer (Scolytus rugulosus)

Description:

Small brown or black beetle 1/10" long, cylindrical in form. Larvae is pinkish with a brown head and is found beneath the bark in the cambium area. They leave tiny holes the diameter of a pencil head. Holes can be numerous and resemble a shotgun blast. They attack weakened trees or sunburned and injured parts of healthy trees. There are 2-3 generations a year and the insects spread the disease cystos porina (see disease section).

Control:

1. Cultural practices described in the OMP (pruning, sanitation, and irrigation).
2. Prevent or repair sunburned areas.

Sunburn on trees causes cracking and permits entry for many boring insects. Young trees should be wrapped or painted with white latex paint. Older trees should have loose bark removed and southerly and westerly facing branches painted white.

DISEASE PROBLEMS

THE MAJOR DISEASES OF TREES AT JOHN MUIR NATIONAL HISTORIC SITE

Brown rot - the pathogen is a fungi Monilinia fructicola or Monilinia laxa. The symptoms are twig blight, bud blight, dieback, cankers, fruit decay and mummies.

Control includes:

1. Removal of all infected wood and mummies
2. The application of 3 sprays of dormant oil and COCS

Threshold - none, any brown rot is too much.

Action Level - preventive and remedial measures are called for at this time.

Cystosporina - Eutypa armeniacae

The pathogen is the assexual stage which is cystosporina.

The symptoms are cankers, dieback, and oozing

Control: Prune 2-3' below the infected area, but only in dry weather since the pathogen is spread by rain. Practice sanitation and remove all mummies and clippings from the site.

Threshold: none

Action Level - As soon as diagnosed; we are presently enacting remedial measures. There is no chemical control.

Crown Gall - Pathogen is the bacterium Agrobacterium tumefaciens.

Symptoms: Galls or tumors begin as small white overgrowths and become convoluted and blackened as they age. Severely diseased plants produce small chlorotic leaves.

Control:

1. Since the bacterium can only enter through a wound, careful cultivation is required. All pruning tools must be sterilized in bleach after being exposed to crown gall.
2. Heat can control the organism and soil solarization can be helpful in this effort.
3. A competing bacterium can control disease and it is marketed as Galltrol.

Powdery Mildew - pathogen is a fungus Sphaerotheca pannosa

Symptoms: Leaves powdery white and some spots on the fruit.

Control: Three sprays with copper; one at petal fall, one two weeks later at pit hardening, and a third during dormancy.

Fireblight - Bacterium - Erwina amylivora

This disease is spread by pollinating insects, wind, and rain, and by holdover cankers. Appearance of fireblight is a temperature--related phenomena and can be monitored in terms of degree days. We are presently assembling more data on this process.

Control:

Remove limbs 6-12" below the infected area and burn or remove the clippings from the site. It is not true that the disease is spread on pruning tools despite traditional claims. Spray streptomycin at 100 ppm beginning at 60 degrees in May and spray every 4-5 days until the bloom is over. Another alternative which we will try first is to hang small bottles of the mycin and let the pollinators spread the mycin as they spread the pathogen. Fertilize the pears minimally or not at all since the young growth is especially susceptible to the fireblight infection. The copper spray will also help, but would not be effective by itself.

Peach Leaf Curl - Taphrina deformans

Symptoms: curled lumpy leaves, with a crusty white coating of spores. The trees will lose the first set of leaves and producing the second set weakens the tree and causes decline.

Life Cycle: winters over in mummies and one mummy can reinfect an entire orchard.

Control:

Sanitation remove infected leaves and all mummies as soon as they appear. The three sprays of copper as outlined in the spraying program will control the disease, the first will also control the peach blossom blight.

Entomosporium Leaf Spot - Cause - fungus Entomosporium maculatum

Symptoms: brown lesions on leaves, sunken black spots on fruit and twig cankers.

Control:

1. Fungicide treatment as described in the spray program.
2. Sanitation.

Armillaria Root Rot - Oak Root Rot - Cause - Armillaria mellea (a fungus)

Symptoms:

1. decline in vigor, wilting, yellowing foliage
2. cream-colored fungus between the bark and wood in the trunk and roots below soil level.

Spread - the problem is spread by man carrying infected wood or by flood water.

Control:

1. Expose the base of the tree for several months, remove and burn all diseased wood.

2. Fertilize to stimulate growth
3. Plant resistant species

MECHANICAL AND CULTURAL OPERATIONS

Weeds - weeds are eliminated by cultivation with a tractor, a small roto-tiller, weed eaters and hoes. This has proven effective in the past and no herbicides are required.

Banding - banding trees with burlap will be employed to trap coddling moth
- all of the orchard trees will be banded with tanglefoot to prevent crawling insects, particularly ants from entering the trees. This has proven very effective to date.

Pruning - elimination of diseased and infested limbs by pruning is very effective with fireblight, aphids, webworm tent caterpillar, and tussock moth to mention just a few.

Sanitation - removal of all infested leaves, fruit, and branches prevents the spread of the disease and eliminates the pathogen for the following year. It is essential that all clippings be removed or chipped up for the elimination of disease.

Painting - painting trunks and southerly facing branches with white latex paint prevents sunburn and the resultant cracking. This prevents the entry of many problem insects.

Traps - Although the purpose of sticky traps and pheremone traps is monitoring, they are also removing insects from the population and the gene pool.

This column, developed by the staff of the Center for the Integration of the Applied Sciences, a division of the John Muir Institute, under a Cooperative Agreement with the U.S. Environmental Protection Agency (EPA), is a regular feature of the *IPM Practitioner*. Information contained in this column was not reviewed in advance by the EPA, and the authors are solely responsible for its contents.

IPM for the Japanese Beetle

Introduction

The Japanese beetle, *Popillia japonica*, continues to be a serious pest of a number of crops and ornamentals. Although today it is nowhere present at the densities recorded during the 1920s and '30s, local populations can still build to levels at which considerable damage to host plants will occur.

The Japanese beetle was first discovered in the United States at Riverton, N.J. in 1916. Prior to its discovery in this country it was only known to occur in Japan where it was considered a minor pest. In the middle eastern United States the beetles found both a climate very similar to that of their native habitat and large expanses of suitable breeding sites. Absence of the natural enemies which kept them below the economic injury level in Japan was the crucial element of this new area that allowed the beetle populations to build to extremely high levels. The spread of the beetles throughout New Jersey and into neighboring states was rapid in spite of concerted efforts to contain them. Today the Japanese beetle is found in practically all states east of the Mississippi.

Basic Biology/Life Cycle

Mated females generally burrow into the ground late in the afternoon to lay eggs. Favored sites of oviposition are grassy areas such as turf, pastures, and meadows with moist loamy soil. Closely cropped grass is preferred.

The white, spherical-to-elliptical eggs hatch in about two weeks. The larvae, or grubs, that emerge from these eggs are completely white with 3 pairs of legs and chewing mouth parts. Each larva assumes a curled, comma-like position in its individual earthen cell. There are three larval instars, all of which may be distinguished from other scarab larvae by the V-shaped arrangement of the spines on the underside of the last abdominal segment (fig. 1). The grubs feed on the roots of a wide variety of ornamental plants, field crops, and grasses.

Emergence of the adults begins around the middle of June in Maryland and Delaware and the third week of June in New Jersey, Ohio, West Virginia, and southeastern Pennsylvania.

The adult beetles are known to feed on close to 300 different plants. Generally, leaf tissues between the veins are consumed as are portions of the blossoms and fruits. Skeletonized leaves eventually wilt and fall from the plant. The beetles are most active and feed most extensively between 9 a.m. and 3 p.m. on warm, clear summer days, as they prefer to feed in areas exposed to direct sunlight. Plants in densely wooded areas are rarely attacked.

Monitoring

Estimates of the extent of feeding by adult beetles on favored host plants has been used as an index of their abundance. A more accurate estimate of beetle populations can be made by sampling the grub population in the soil prior to emergence. Since natural mortality factors greatly reduce the beetle population between the egg and adult stages, the most accurate surveys will be made just prior to adult emergence in late spring (early to mid-June in Washington, D.C.).

Larval samples can be selected either along a transect or randomly throughout the area. Each sample should be taken by cutting the turf on 3 sides of a 1' square using a spade. The turf can then be lifted up by using the spade to separate the sod from the soil below. Ideally, 1"–2" of soil should remain on the sod sample which can then be examined for grubs. (A well-maintained turf will normally not show any signs of injury when grub populations are below 10 per sq. ft. By contrast, the high populations of 150–200 grubs per sq. ft. recorded in the 1930s often completely severed the aerial portions of the grass from the roots.)

Since there are several other species of scarab grubs that are found in turf and are superficially similar to Japanese beetle grubs, it is imperative that sampled grubs be positively identified (see fig. 1).

Traps using chemical lures have been used extensively since the 1930s to monitor beetle populations. The trap which has proven best consists of a funnel, a baffle with bait container, and a receptacle for captured beetles. Beetles attracted to the bait strike the baffle which extends above the funnel, fall into the funnel, and are collected in a container. With this design, optimal performance is achieved when the funnel has a 60°–80° pitch with a ¼" opening at the narrow end and the baffle projects 4"–6" above the lip of the funnel and 2" or more into the funnel. Traps painted chrome yellow have been found to be most attractive to beetles.

The chemical lure currently found to be most effective is a 7:3 mixture of phenylethyl propionate (PEP) and eugenol. Addition of 3 parts geraniol to this mixture further increases effectiveness.

A sex pheromone isolated from virgin female Japanese beetles and subsequently synthesized is currently being used by J.T. Baker Chemical Company in their commercially available "Bag-a-Bug" trap. The pheromone itself should be available next year from Albany International Chemicals Division, Columbus, Ohio. According to J.T. Baker Chemical Company, the use of the pheromone increases the effectiveness of the traps 2–5 times over the floral lure alone.

Summary of Japanese Beetle IPM

1. Identify adult beetles on host plant.
2. Decrease adult populations using traps and handpicking.
3. Use repellents on favorite host plants during peak abundance of beetles.
4. Survey to determine where larvae are breeding.
5. Treat high grub populations with milky disease spores. Do not use pesticides in areas treated with milky disease.
6. Rotate crops with clover and other plants on which grubs do not thrive.
7. Lime soil to neutral pH to decrease grub populations.
8. Where possible, replace susceptible plants with more resistant species and varieties.
9. Adjust planting dates so bloom and fruit set miss peak of adult activity.

Milky Disease and Other Biological Controls

A number of native species of birds such as grackles, starlings, meadowlarks, cardinals, and catbirds will feed readily on adult beetles. Several native mammals (short-tailed shrew, skunk, etc.) as well as domestic animals (chickens, turkeys, ducks, hogs, etc.) have also been observed feeding on Japanese beetles—adults and grubs. Between 1919 and

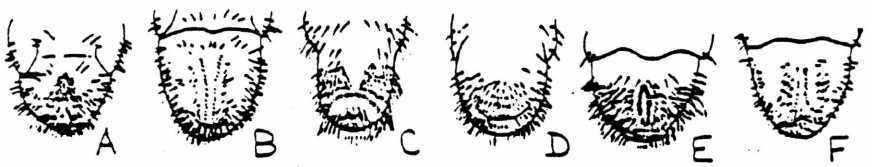

Fig. 1. V-shaped arrangement of the spines on the underside of the last abdominal segment characteristic of the larva—or "white grub"—of the Japanese beetle *Popillia japonica* (A), contrasted with appearance of five other common species.

1936, soon after the beetles were discovered in this country, a large-scale effort to import biological control agents was launched by the former U.S. Bureau of Entomology. Of the 26 species imported, [illegible] species became established (see table . In addition, a nematode, *Neoaplec-ina glaseri*, which can cause up to 81% mortality in grub populations was discovered in New Jersey in 1929. It is relatively easy to mass-culture and may have promise for use in Japanese beetle IPM.

By far the most important natural enemies of the Japanese beetle are the milky disease bacteria *Bacillus popillae* Dutky and *Bacillus lentimorbus* Dutky. These bacteria, particularly *B. popillae*, have been largely responsible for the widespread reduction in beetle populations over the last 40 years.

First isolated in 1933 from diseased grubs, *B. popillae* was soon found to be as virulent to Japanese beetle grubs and several other scarab grubs as it is harmless to other organisms including human beings. Between 1939 and 1951, the U.S. Department of Agriculture alone applied 178,000 lbs. of spore dust containing 100 million spores/gm to 101,000 acres in 14 states and the District of Columbia.

Milky disease does not appear to have lost its effectiveness over the years and continues to suppress grub populations. The pathogen persists in those areas where it has been colonized and spreads naturally to new, uncolonized areas. In 1973 and 1974, high populations of Jap-ese beetles observed in Connecticut re attributed to attenuation of the bac-erium, but this has yet to be confirmed.

Many outbreaks of Japanese beetles can be traced to changes in land use that create new uninoculated breeding sites. For example, the conversion of woodland areas to residential use with large expanses of turf creates new breeding sites in which milky disease bacteria are not present. The natural spread of the milky disease in these areas would take many years and, in the meantime, adult populations of Japanese beetles may reach very high levels. Therefore, in new housing developments constructed in areas where the Japanese beetle is present, the developer should treat all turf areas in the community with milky disease spores as part of the construction package. This will provide the best insurance against future outbreaks of the beetles.

Whenever a soil survey indicates a high population of grubs in late spring and the absence or low incidence of milky disease in the fall, the area should be considered for treatment with milky disease spores. Since as much turf as possible in a given community should always be treated, a cooperative effort among property owners is always best.

Treatment with milky disease spores ll not initially affect high adult popu-ions. However, as the bacterium becomes established, decreases in the number of adults will follow. This may take one to several years depending largely on soil temperatures. Temperatures at or above 21°C will insure the most rapid development of the disease.

TABLE 1. IMPORTED NATURAL ENEMIES OF *POPILLIA JAPONICA* ESTABLISHED IN THE UNITED STATES

Species	Order/Family	Association with Host	Adult Food Source
Tiphia vernalis	Hymenoptera/Tiphiidae	solitary larval ectoparasite	honeydew
Tiphia popilliavora	Hymenoptera/Tiphiidae	solitary larval ectoparasite	wild carrot
Hyperecteina aldrichi	Diptera/Tachinidae	solitary adult endoparasite	honeydew and nectar, particularly *Polygonum reynoutria*
Dexilla ventralis	Diptera/Tachinidae	solitary larval endoparasite	nectar?
Prosena siberita	Diptera/Tachinidae	solitary larval endoparasite	nectar of umbelliferous plants

Traps

Traps can be important control tools in an IPM program for the Japanese beetle. Mass trapping has been shown to be effective in reducing beetle populations when large numbers of traps are employed throughout an entire community. In using traps it should be remembered that they may actually attract beetles into an area. To avoid this, traps should be placed around the perimeter of the area to be protected. In this way, beetles are captured as they fly into the protected zone. J.T. Baker Chemical Company suggests that its "Bag-a-Bug" trap be placed at intervals of 150'–200' around the perimeter.

Since dead and decaying beetles are repellent to other beetles, it is important to remove beetles from traps and dispose of them at regular intervals. Some traps use screen containers to collect the beetles; these tend to keep beetles alive longer than do closed containers. Traps should be placed at least 1' off the ground in a bright sunny location. They should never be placed in or near foliage.

Repellents

Leaf deposits of both toxic and nontoxic materials are repellent to beetles. The more conspicuous the deposits the less likely beetles are to alight. Hydrated lime has been shown to be an effective nontoxic repellent. The only difficulty with the use of lime is that it does not adhere well to foliage and is easily washed off by rainfall. A small amount of aluminum sulfate added to a suspension of lime in water (20 lbs. of hydrated lime and 3 lbs. of aluminum sulfate in 100 gal. of water) increases the adhesion considerably. Neem oil is a newly discovered repellent for Japanese beetles that is currently being researched by the U.S. Department of Agriculture. Derived from the neem tree, a native of India, neem oil is showing potential for future use in Japanese beetle IPM.

Handpicking

Handpicking can be effective in reducing light infestations on a few plants. Any method that reduces the number of f-males, particularly early in the seasc will tend to reduce the grub population and therefore the adult population of the following year. One method that is both simple and effective is to shake the beetles from plants before 7 a.m. when they are still sluggish and will merely drop to the ground and feign death. If a large sheet or drop cloth is placed under the plants, large numbers of beetles can be collected and disposed of quite easily. Captured beetles may be killed by immersion in warm soapy water.

Applying Milky Disease Spore Dust

Milky disease spore dust should not be broadcast over an area but should be applied in discrete amounts at 2'–10' intervals. Normally one teaspoon of spore dust is applied at each point. Applied at this rate at 4' intervals, 20 oz. of spore dust is sufficient to treat 5,000 sq. ft. of turf. The commercial formulation "Doom" is produced by Fairfax Biological Laboratory, Clinton Corners, N.Y. 12514 and is available at most nurseries.

If large areas are to be treated, a simple device can be constructed out of a 1 lb. coffee can and a broom handle. The bottom of the can is perforated 15 times with a 10-penny nail over an area of 1 sq. in. The can is bolted to the broom handle so that the bottom is 4" from the end of the handle. The can is then filled ¾ full of spore dust. To dispense the dust, the end of the broom handle is tapped briskly against the ground at the spots to be treated.

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—G. G. Soares, Jr.

Appendix B

Field Log Sheet

Lehman Orchar ntenance Record

Date _____

Tree Number	% Soil Moisture	Amount Watered	Pests Monitored	Pesticides Used	Fertilizers Used	Pruning	Remarks

Appendix C

Database Structure

Structure for database: C:ORCHARD.dbf
Number of data records: 1
Date of last update   : 01/09/90

Field	Field Name	Type	Width	Dec
1	TREE_NUM	Character	3	
2	SPECIES	Character	20	
3	VARIETY	Character	10	
4	COMMONNAME	Character	8	
5	UTM_EAST	Numeric	7	3
6	UTM_NORTH	Numeric	8	3
7	LOCATION	Memo	10	
8	PARENTS	Character	15	
9	PROP_DATE	Date	8	
10	PLANT_DATE	Date	8	
11	DEATH_DATE	Date	8	
12	GEN_HEALTH	Character	4	
13	MAINT_1988	Memo	10	
14	MAINT_1989	Memo	10	
15	MAINT_1990	Memo	10	
** Total **			145	

Appendix D

Pesticide Use Log

UNITED STATES DEPARTMENT OF INTERIOR
NATIONAL PARK SERVICE
PESTICIDE USE LOG

PARK:
REGION:
YEAR:

LOCATION/ PROJECT NO.	DATE	APPLICATOR	TRADE NAME	ACTIVE INGREDIENT	EPA REG. NUMBER	PEST	AMOUNT OF PRODUCT	AREA TREATED	AMOUNT 100% ACTIVE INGRED.

United States Department of the Interior

NATIONAL PARK SERVICE
WESTERN REGION
450 GOLDEN GATE AVENUE, BOX 36063
SAN FRANCISCO, CALIFORNIA 94102

IN REPLY REFER TO:

H4217(WR-RH)

March 19, 1990

MAR 26 1990

Lee Kestrue
for CLAUDIA NISSLEY
Director, Western Office

Ms. Claudia Nissley
Chief, Western Office of Review and Compliance
Advisory Council on Historic Preservation
730 Simms Street, Room 450
Golden, Colorado 80401

Dear Ms. Nissley:

The Western Region proposes to approve an Orchard Management Plan for Lehman Orchard, a property listed on the National Register of Historic Places, located in Great Basin National Park, Nevada.

The plan proposed actions to preserve the historic orchard. In accordance with Section 106 of the National Historic Preservation Act of 1966 and pursuant to Federal Regulations of the Advisory Council on Historic Preservation (36 CFR 800), we have considered the effects of the undertaking. We feel that an effect will occur. We also feel that the effect will not be adverse. We have consulted with the State Historic Preservation Officer (copy enclosed) who concurs in the finding.

We will appreciate your review and comment. If you have any questions, please contact Albert Hendricks, Superintendent at (702) 234-7331 or Tom Mulhern of this office at (415) 556-8376.

Sincerely,

for Stanley T. Albright
Regional Director, Western Region

Enclosures

BOB MILLER
Governor

STATE OF NEVADA

ROLAND D. WESTERGARD
State Historic Preservation Officer

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

DIVISION OF HISTORIC PRESERVATION AND ARCHEOLOGY
Capitol Complex
Carson City, Nevada 89710
(702) 687-5138

March 8, 1990

Stanley T. Albright
Regional Director, Western Region
National Park Service
450 Golden Gate Avenue, Box 36063
San Francisco, CA 94102

Dear Mr. Albright:

This letter is in response to your request for comments on a proposed Orchard Management Plan for Lehman Orchard, a property listed on the National Register of Historic Places, located in the Great Basin National Park. The plan recommends protection of existing historic trees and their gene pool, as well as maintenance actions for the orchard.

The staff has reviewed the plan and agree that although an effect will occur, it will not be adverse. I concur with the National Park Service that the implementation of the plan will have no adverse effect on the Lehman Orchard.

The Division is pleased to see National Park Service develop a management plan for the orchard. We appreciate the opportunity to comment on proposed activities.

Sincerely,

Alice M. Baldrica

Alice M. Baldrica, Deputy
State Historic Preservation Officer

AMB:emt