Using Vegetation Biomonitors to Assess Air Pollution Injury in National Parks

Milkweed Survey

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USING VEGETATION BIOMONITORS TO ASSESS AIR POLLUTION INJURY IN NATIONAL PARKS

Milkweed Survey

Natural Resouces Report Series No. 85-1

by

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FOREWORD

This report reproduces a manual developed by the National Park Service's Air Quality Division in 1984 and 1985. The manual is being used by park staff to evaluate conditions on common milkweed plants that indicate the presence or absence of air pollutants. This work is done only in park units where the plant occurs, which is the midwest and central eastern states. Any reader may follow the manual for their own purposes as they so wish. Users in national parks, however, are requested to do so in conjunction with the Air Quality Division Annual Milkweed Survey by contacting the authors.

INTRODUCTION

Air pollution has become an increasingly common problem in many sections of the United States. Some national park units do not have the pristine air quality that is a part of our national heritage. Most of the contaminants found in the air today are the result of mans' activities. Sources of pollutants can be localized, such as smelters and power plants, or more regional, for instance large urban areas or busy highway corridors. Many substances are present in polluted air, but the ones of common concern to pollution scientists are ozone (O_3), sulfur dioxide (SO_2), fluoride (F) and trace elements (Zn, Cd, As, Cu, Pb, etc.). On a national level, ozone is believed to be the most ubiquitous pollutant and the cause of most of the injury to sensitive biological resources. Few national parks in our country are free of ozone pollution.

Extensive air pollution research has shown that plants are far more sensitive than animals to air pollution. The Research Branch of the National Park Service's Air Quality Division (AQD) consequently strives to identify susceptible plant species and use these species as biological indicators (biomonitors) of air pollution stress. Lichens, mosses, conifers, broad-leaved trees, shrubs, herbs and grasses all have member species that are susceptible to air pollution. The difference in species susceptibility to air pollution is still being studied. In general, leaves are the most sensitive organs of the plants and species with mesophyllous (water-loving) leaves are often more susceptible to air pollution.

To evaluate the effects of air pollutants on biological resources in national parks, the AQD has undertaken a variety of scientific approaches. A major goal is to determine the geographic extent and severity of air pollution injury in each park. Fumigation studies are designed to increase our knowledge of the susceptibility of different species to an air pollutant. Once the susceptibility of a species is known, a visible injury survey of the sensitive species can be conducted. If a more extensive study of the species is warranted, i.e., high pollutant levels have been recorded or injury is fairly common, short-term or long-term biomonitoring plots can be established and air pollution injury and plant vigor can be more extensively quantified. Long-term trends in air pollution effects can be determined from these plots. Typically, air pollution susceptible species of conifers or hardwood trees are utilized for this purpose. Another approach to biomonitoring of air pollution effects is to plant air pollution susceptible species, native to the park unit, in a common garden near ambient air pollution monitors. The biomonitoring garden then indicates to the researcher what pollutant levels are toxic to the species under the environmental conditions of the garden. Biomonitoring gardens are most useful when used in conjunction with field plots of the same species. When trace elements or heavy metals are suspected air pollutants, sampling of park vegetation using a sophisticated sampling technique, designed to deal with natural elemental variation, for levels of elements is performed. Trace elements and heavy metals can have devastating impacts on ecosystems because the elements accumulate in the plants and soils and in the food chain.

The milkweed study is an example of short-term biomonitoring plots containing a native species highly sensitive to ozone. The purpose of the milkweed plots is to identify parks and regions where air pollution stress is greatest and to compare the severity of ozone stress from one year to the next. The species of milkweed used occurs only in the eastern United States. This manual should not be used in western United States parks because *Asclepias syriaca* L. does not occur there.

The 1984 milkweed survey showed that parks in the middle to southern part of the Mid-Atlantic Region and the eastern portion of the Midwest Region had the greatest amount of ozone injury on common milkweed.

METHODS

Plot Establishment and Evaluation

Each participating park will identify areas where common milkweed is growing. If the species was observed previously, it will probably be found in the same vicinity since it propogates from underground rhizomes as well as seed. Each park should select a number of sites (1 plot at each site) which satisfy the following criteria. The number of plots per park is dependent on the abundance and distribution of *A. syriaca* within the park and the size of the park. The number of plots per park should be chosen such that:

1. The park is adequately represented throughout the range of *A. syriaca* in the park. Ten (10) plots per park are adequate for most parks. If a park is small in area, then it may not be possible to find 10 plots; in this case a lesser number will suffice.

2. The plots themselves should be as well spaced as possible within the park (including a range of elevations if possible).

3. The plots should not be located immediately adjacent to any roads. They should be at least 30-50 meters from the road to avoid confounding effects of exhause pollutants.

4. Each plot should contain no less than 10 individual plants. There are no limitations on the size of the plot at each site. NOTE: The plants should not be spaced so far apart that the environment changes appreciably, as plant growth may not be constant under variable conditions. Generally, all 10 plants should be within 30-50 meters of each other.

The plots in each park should then be numbered 1-10 and located on a topographic map. From each plot a minimum of 10 individual plants should be selected. Each plant should have 10 to 16 leaves greater than 65% fully expanded or greater than 10 cm in length. Each plant and leaf should be marked in some way, e.g., using paper tags on string (as inconspicuously as possible) to number the plants and waterproof ink, colored yarn, etc. to mark the petiole of each evaluated leaf or pair of leaves. These numbers should be retained for the duration of the study. Each plot should be afforded some kind of protection (e.g., from mowing, etc.) to minimize losses. Staking the plots and running string to the corner plot stakes may suffice to prevent unintentional plot destruction. The plots should not be made permanent, but should be relocatable in future years if the project is continued.

Two ozone injury evaluations are required. The first evaluation should occur between June 15 and June 30. The second evaluation must be between August 15 and August 30. Evaluation of the plots must be performed during these time periods to allow for comparisons of injury between parks.

The investigator will be required to return the following materials to the Air Quality Division following each summer's work:

1. Topographic maps showing plot locations.
2. Pressed leaves showing ozone injury, with written injury evaluations for quality (type of symptom) and quantity (percentage evaluation of amount of injury) assurance checks by the Air Quality Division. These pressed leaves should be collected from one of the plots (with the most injury) after the final (August) evaluation.
3. Data sheets for all plots, with summary data analyses (mean and standard deviations) for each plot.

Visible Foliar Injury Symptoms from Exposure to Ozone

Ozone produces a type of injury on milkweed leaves that is unique and easy to diagnose. This injury typically results in sharply defined, small dot-like lesions which are observed only on the upper leaf surface. These lesions are frequently black-purple in color (see Photos. 2-8). The veins are usually not affected. Pigment formation may produce an overall dark discoloration of the upper leaf surface when lesions are dense and coalesce. Please ignore all other leaf injury symptoms.

The position of injury on the leaf may vary. In general, the location of ozone injury on a leaf is determined by the developmental sequence of tissue maturation in the leaf. Leaf cells that are fully differentiated, have developed intercellular spaces but do not yet have suberized cell walls, are the most sensitive to ozone injury. Consequently acute ozone injury tends to develop towards the tip of younger leaves, in the center of older ones, and at the base of the oldest affected leaves. Foliage frequently exposed to ozone may exhibit injury symptoms all over the upper leaf surface. Leaves ranging from about 65-95% of their full size tend to be the most sensitive to ozone injury.

Procedures for Plot Evaluation

For each plant in each plot (also see explanation of data sheet):

1. Measure the individual heights of the plants from base to apex in centimeters.
2. Count the number of leaves showing ozone injury.
3. Count the total number of leaves on the plant. Do not include apical leaves which are not fully expanded, i.e., those which are still in a vertical position and have not oriented their upper surfaces to the sun (e.g. see Photo. 1. in which the top 5 leaves would not be included). In general, evaluate only leaves that are at least 65% fully expanded.
4. Estimate the percentage of the total leaf area of each leaf that has ozone injury. If the number of mature leaves on the plant exceeds 10 (which usually will occur by the second sampling date) then enter data for the uppermost 10 mature leaves only (See Data Sheet).
5. Record any presence of the monarch butterfly (larvae, chrysalis, butterfly) on each plant (Photo. 10).
6. Record the number of seed pods per plant.

From the data collected the investigator should then calculate the means and standard deviations and enter these on the data sheet in the spaces provided.

Monarch Butterfly

The monarch butterfly (*Danaus plexippus* Linn.) has a close ecological relationship with the milkweed plant. Eggs are deposited on the plant and the developing larvae feed on the leaves, ingesting cardiac toxins in the leaves which render the mature butterflies unpalatable to predators.

The monarch is one of the few North American butterflies that migrates to South America for the winter. Several generations are produced each winter in South America before the monarch returns to its summer breeding home in North America. The returning monarchs then produce two generations before returning to South America in the fall to repeat the cycle.

Monarch survival is tied closely to the chemical defense system derived from the milkweed toxins and to the nutrition supplied to the developing larvae from the leaves of the plant. *Asclepias syriaca* is an important species and a common host for the monarch. The relatively high susceptibility of common milkweed to ozone injury and the prevalence of ozone injury on milkweed plants throughout the eastern United States suggests a hypothesis that ozone injury on milkweed leaves may affect the life cycle of the monarch butterfly. In order to determine if monarchs are feeding on park milkweeds, record the presence of any developmental stage of the monarch butterfly (Photo. 10) if it is observed on any plants in the plots (See Data Sheet).

Quality Control of Symptom Evaluation

Pressed leaves should be prepared to verify the ozone injury symptoms (black-purple stippling) and to evaluate the quantification of O_3 injury on the leaves. The leaves removed for pressing should be taken from plants in the plot with the most injury after the final injury evaluation. The leaves should represent a gradation of O_3 injury found at the plot, e.g., include leaves with the greatest and the least levels of injury plus some intermediate levels. Four (4) leaves per plant from 5 plants will be sufficient. Pressed leaves and the evaluation of the percentage of O_3 injury on those individual leaves should be returned to the Air Quality Division Office after the last period of sampling. The leaf data should be included in the package containing the pressed leaves, which should be mailed with the pressed leaves unmounted (do not glue the leaves to any surface since the underside of the leaf must be examined to verify the ozone injury).

The following procedure is recommended for the evaluation, collection, drying and mailing of the leaves for the quality assurance check:

1. Evaluate the ozone injury on the plants in the plots as described previously in this manual.
2. Select twenty (20) of the evaluated leaves as representative of high, low and intermediate levels of injury (include leaves to represent the whole range of visible injury).
3. For each leaf, record on a business-size envelope (8.5 x 4 inches) the plot, plant and leaf number, the date of collection and the percent evaluation of visible injury (the percentage of the total leaf area with black-purple stippling). The percent ozone injury recorded on the envelope should be the same as that recorded on the data sheet for that leaf.
4. Place each leaf in an envelope and repeat this procedure until twenty leaves have been collected.
5. Return with the leaves to the building where the leaves are to be dried.
6. Remove each leaf from each envelope and place each leaf individually between two sheets of paper (newspaper, etc.). Carefully copy the information (plot, plant, leaf number, date and % visible injury) from the envelope to the sheets of paper. Place the sheets of paper containing the leaf (with the appropriate identification) into the plant press for drying. If there is none available then a simple press may be made by placing the leaves (separately and with identification) between sheets of newspaper and inserting between two sheets of corrugated cardboard. Sandwich this between 2 pieces of wood or hardboard and close as tightly as possible using rope or weights. The press should be left in a well ventilated room to allow the leaves to dry out (this will only take a few days in dry climates).

Diagram of Leaf Press

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  <--- wood
0000000000000000000000000000000000000000000  <--- corrugated cardboard
///////////////////////////////////////////  <--- newspaper
              ==============                 <--- leaf
///////////////////////////////////////////
0000000000000000000000000000000000000000000
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

7. When the leaf is dry (brittle), remove it from the sheets of paper and carefully replace the leaf into the correct envelope (same envelope as in #3 above). Combine all twenty envelopes (8.5 x 4 inches) and mail in a larger envelope to the Air Quality Division Office. It is imperative that the leaves be clearly marked as to location and date of collection and contain a clear, quantitative evaluation of the percentage of O_3 injury on each leaf.

If there are any questions relating to any of the procedures, please contact the author for clarification.

NATIONAL PARK SERVICE - AIR QUALITY DIVISION - MILKWEED SURVEY DATA SHEET

COLLECTED BY:	PLOT LOCATION:	SITE CONDITIONS:
	NPS UNIT:	MOISTURE:
	LOCALITY:	ELEV (FT):
	TOPO MAP:	GENERAL COMMENTS:
DATE:	PLOT NO (1-10):	

PLANT NUMBER	HEIGHT (CM)	NUMBER INJURED LEAVES	TOTAL NUMBER LEAVES	% INJURED LEAVES PER PLANT	PERCENT LEAF AREA INJURED BY OZONE PER LEAF (BLACK/PURPLE STIPPLING)					MEAN % LEAF AREA INJURED	MONARCH BUTTERFLY (STAGE & NUMBER)	NUMBER OF SEED PODS
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
TOTAL					//////////////////////////							
MEAN					//////////////////////////							
S.D.					//////////////////////////							

Explanation of Data Sheet

1. PLANT NUMBER: - From 1-10.

2. HEIGHT (CM): - Height of each milkweed plant in centimeters, from base to apex.

3. NUMBER LEAVES INJURED: - Number of leaves on the plant showing the black-purple stippling of ozone injury (Photos. 2-8).

4. TOTAL NUMBER LEAVES: - Total number of mature (> 65% fully expanded or > 10 cm in length) leaves on each plant. Typically the leaves below the newly initiated whorled leaves at the shoot apex (Photo. 1).

5. PERCENT INJURED LEAVES/ PLANT: - Number of leaves showing ozone injury per plant divided by the total number of mature leaves per plant times 100.

6. % LEAF AREA INJURED: - Visual estimate of the percentage of the total area of each individual leaf showing ozone injury (Photos. 2-5).

7. MEAN % LEAF AREA INJURED: - Mean of the percent leaf area injured per plant. For each plant sum the individual percent injury for the ten evaluated leaves and divide by 10.

8. MONARCH BUTTERFLY: - Record the total number of any developmental stage (larva, chrysalis, butterfly) of the monarch butterfly on each plant (Photo. 10).

9. SEED PODS: - Record the total number of seed pods on each plant.

To summarize each plot calculate the mean and standard deviation for all parameters (See data sheet).

BOTANICAL CHARACTERISTICS OF ASCLEPIAS SYRIACA L.

The family Asclepiadaceae is characterized by plants that have a thick white sap exuding from any cut or broken surface. The flower structure is unusual, with the tips of the five stamens being more or less joined with each other and also joined with the broad stigma, which is supported by two styles, one for each of the two ovaries. The pollen of each stamen is lumped in two waxy masses, each one connected with the mass of the adjacent stamen. The fruit is a follicle (pod); two can be obtained from each flower but few of the flowers result in pod formation. The seeds are tipped with long silky hairs for wind dispersal.

The genus Asclepias is characterized by flowers that have a deeply cleft corolla, with the five lobes turned back and downward thus concealing the calyx. A crown (corona) is formed of five cups above the junction of the corolla lobes, each one a short tube. From within each cup rises a curved horn, its point directed toward the stigma. The adjoining masses of pollen are tightly attached by a triangular gland that lies between them. Insects can get caught in this pollen mass and if they are large enough they will carry it off to the next flower visited. Flowers of this genus are borne in large clusters on stalks that all radiate from a central point (an umbel) at the tip of a branch or stem or in the axil of a leaf.

The species Asclepias syriaca L. (common milkweed) is recognized by a solitary, simple stem, 0.5-2 m tall, tomentulose to glabrate. The leaves are opposite, widely elliptical to ovate-elliptic, 6-30 cm long, 3-10 cm wide, and thick. The surface of the leaf is tomentose beneath and glabrate above. The petioles are short and thick. There are typically 2-6 umbels in the upper nodes which are 5-10 cm broad. The flower peduncles are 3.5-8.5 cm long and the pedicels are 3-4 cm long. The corolla is rose or greenish-white with the lobes 7-9 mm long and reflexed. The corona is 3-6 mm in diameter with the lateral hood margins having a single median tooth. The horns nearly equal the hoods and arch close above the gynostegium. The follicles are erect, 8-12 cm long, 2.5-3.5 cm broad and muricate. Flowering period is from June to August. The plants are common along roadsides, in fields and meadows. The species is usually found from New Brunswick to Saskatchewan and south to Georgia and Tennessee and west to Iowa and Kansas.

1. ASCLEPIAS L. Milkweed

Perennial herbs, usually with milky sap. Stems erect, spreading or decumbent, usually simple and often solitary. Leaves opposite to subopposite, or sometimes whorled, rarely alternate. Corolla lobes reflexed, rarely erect or spreading; the filaments elaborated into five hoods forming a corona around the gynostegium, corona horns present in most of our species.

I. *Flowering Specimens*

Petals predominately white or green.
  Leaves linear, 10X or more as long as wide.
    Leaves whorled ———— 3. *A. verticillata.*
    Leaves opposite or subopposite.
      Corona 5-8 mm broad; umbel solitary ———— 14. *A. michauxii.*
      Corona 2-3 mm broad; umbels 2-5 ———— 18. *A. longifolia.*
  Leaves lanceolate to ovate, less than 10X as long as wide.
    Gynostegium elevated 4 mm or more above hoods; plants usually less than 3 dm tall ———— 20. *A. pedicellata.*
    Gynostegium not elevated above hoods; plants usually more than 3 dm tall.
      Inflorescence sessile or subsessile.
        Corona 2-3 mm broad ———— 19. *A. viridiflora.*
        Corona 5-9 mm broad.
          Horns longer than hoods, exserted apically; stem and leaves lightly tomentose ———— 15. *A. tomentosa.*
          Horns shorter than hoods; exserted laterally; stem and leaves densely tomentose ———— 16. *A. obovata.*
      Inflorescence pedunculate.
        Longest pedicels 3-8 cm long, often lax.
          Lower surface of leaf glabrous or essentially so; horns 1.5-2X as long as hoods ———— 7. *A. exaltata.*
          Lower surface of leaf tomentose; horns equalling the hoods ———— 10. *A. syriaca.*
        Longest pedicels 0.5-2.5 cm long, may be reflexed, rarely lax.
          Corona 2-3 mm broad; umbel 2-3 cm in diam.; horns longer than hoods ———— 2. *A. perennis.*
          Corona 4-8 mm broad; umbel 3-8 cm in diam.; horns shorter than hoods.
            Four largest leaves appearing whorled; corolla lobes less than 8 mm long ———— 9. *A. quadrifolia.*
            Leaves all opposite; corolla lobes more than 6 mm long ———— 12. *A. variegata.*
Petals predominately rose, purple, or red to yellow.
  Leaves alternate to subopposite, or some appearing whorled.
    Leaves more than 12, alternate to subopposite; flowers red to yellow; sap not milky ———— 4. *A. tuberosa.*
    Leaves 4-10, the 4 largest appearing whorled, or rarely subopposite; flowers pink; sap milky. ———— 9. *A. quadrifolia.*
  Leaves opposite.
    Leaves linear to narrowly lanceolate, 10X or more as long as wide.
      Corona 4-5 mm broad; leaves linear; follicles on erect pedicels ———— 17. *A. cinerea.*
      Corona 7-10 mm broad; leaves lanceolate; follicles on deflexed pedicels ———— 6. *A. lanceolata.*
    Leaves lanceolate to ovate, 6X or less as long as wide.
      Leaves sessile, auriculate.
        Plant erect; inflorescence usually solitary and terminal; corona 5-8 mm broad ———— 8. *A. amplexicaulis.*
        Plant spreading-ascending; inflorescences 2-5, from upper nodes; corona 3-5 mm broad ———— 11. *A. humistrata.*
      Leaves petiolate to subsessile, not auriculate.
        Leaves glabrous beneath, or pubescent along veins.
          Leaves subsessile, lanceolate; petals rose red ———— 5. *A. rubra.*
          Leaves petiolate, ovate to ovate-lanceolate; petals pink to white ———— 9. *A. quadrifolia.*
        Leaves pubescent beneath.
          Hood margin with a single median triangular tooth; follicles muricate ———— 10. *A. syriaca.*
          Hood margin without a median tooth; follicles smooth.
            Hoods 5-7 mm long; leaves ovate, 4-8 cm wide ———— 13. *A. purpurascens.*
            Hoods 3-4 mm long; leaves lanceolate, usually 1-3 cm wide ———— 1. *A. incarnata.*

II. *Fruiting Specimens*

Leaves alternate to subopposite or whorled (only the four largest appearing whorled in #4)
  Leaves alternate; sap not milky ———— 4. *A. tuberosa.*
  Leaves subopposite or whorled.
    Leaves whorled, or appearing so.
      Leaves linear; follicle 4.5-8.5 cm long ———— 3. *A. verticillata.*
      Leaves ovate to elliptic; follicle 8-11 cm long ———— 9. *A. quadrifolia.*
    Leaves subopposite.
      Leaves pilose or hispid, rarely linear ———— 4. *A. tuberosa.*
      Leaves glabrous or weakly pubescent, linear.
        Follicle terminal ———— 14. *A. michauxii.*
        Follicle axillary, from an upper node ———— 18. *A. longifolia.*
Leaves opposite.
  Follicle pendent ———— 2. *A. perennis.*
  Follicle erect.
    Follicle muricate ———— 10. *A. syriaca.*
    Follicle smooth.
      Leaves glabrous beneath.
        Leaves linear.
          Leaves 1-2 mm wide ———— 17. *A. cinerea.*
          Leaves 2-7 mm wide.
            Follicle terminal ———— 14. *A. michauxii.*
            Follicle axillary from an upper node ———— 18. *A. longifolia.*
        Leaves not linear.
          Leaves ovate to elliptic, auriculate.
            Stems erect; follicles from solitary terminal inflorescence ———— 8. *A. amplexicaulis*
            Stems spreading-ascending; follicles from axillary inflorescences at upper 2-5 nodes ———— 11. *A. humistrata.*
          Leaves lanceolate or lance-ovate, not auriculate.
            Follicle 8-10 cm long; plant of cp. ———— 6. *A. lanceolata.*
            Follicle 12-14 cm long; plant of mts. ———— 7. *A. exaltata.*
      Leaves variously pubescent beneath.
        Leaves linear or lanceolate.
          Leaves linear; plant 1-3 dm tall ———— 20. *A. pedicellata.*
          Leaves lanceolate; plant usually more than 3 dm tall.
            Leaves coriaceous; plant not of moist areas ———— 19. *A. viridiflora.*
            Leaves not coriaceous; plant of marshes, bogs or wet pastures.
              Follicle 6-10 cm long; pedicel erect; leaves pilose-hispid beneath; plant strongly branched ———— 1. *A. incarnata.*
              Follicle 9-12 cm long; pedicel deflexed; leaves hispid along margin; plant weakly, if at all, branched ———— 5. *A. rubra.*
        Leaves ovate to elliptic.
          Leaves tomentose beneath.
            Leaves petiolate, apiculate, lightly tomentose ———— 15. *A. tomentosa.*
            Leaves sessile, mucronate, densely tomentose ———— 16. *A. obovata.*
          Leaves puberulent or weakly pubescent, above or beneath.
            Plant of open upland woods; leaves 2-5 pairs ———— 12. *A. variegata.*
            Plant of swamp forests; leaves 6 or more pairs ———— 13. *A. purpurascens*

Source: Manual of the Vascular Flora of the Carolinas. 1979. Radford, A. E., H. E. Ables and C. R. Bell. University of North Carolina Press. Chapel Hill. 1183 pps.

Glossary of Terms Relating to Key

ALTERNATE - borne singly and not opposite; in leaves, one at a node.

ANTHER - the pollen-bearing part of the stamen.

AURICULATE - ear-shaped.

AXILLARY - in an axil (angle between stem and leaf).

CALYX - the outer series of the perianth, used especially when it differs in size , shape or color from the inner or petals.

CARPEL - a simple pistil formed from 1 sporophyll, or that part of a compound pistil formed from 1 sporophyll.

COROLLA - the inner series of the floral envelope; collective name for petals.

CORONA - a crown-like extension of basal portions of perianth segments (may be a modification of the anthers).

DEFLEXED - bent or curved abruptly downward, or backward.

ELLIPTIC - shaped like an ellipse; widest at the center and the 2 ends equal.

EXSERTED - projecting out of, beyond.

FILAMENT - any thread-like body; used especially for that part of the stamen that supports the anther.

FOLLICLE - a dry fruit with 1 carpel and splitting down 1 side only.

GLABROUS - without trichomes or hairs.

GYNOSTEGIUM - fused column of anthers and stigma.

HISPID - provided with stiff or bristly hairs.

HOOD - composite part of corona.

HORN - needle-like (horn-shaped) protrusion from hood.

INFLORESCENCE- the flowering part of a plant, almost always used for a flower cluster.

LANCEOLATE - lance-shaped; several times longer than wide, broadest towards the base and tapering to the apex.

LAX - loose, often used for a soft open inflorescence or for soft drooping stems or foliage.

LINEAR - narrow and flat with sides parallel, like a blade of grass.

MURICATE - a surface roughened by broad or fleshy pointed spines.

NODE	-	the place on a stem where leaves or branches normally originate; the place on an axis that bears other structures; any swollen or knob-like structure.
OPPOSITE	-	leaves 2 at a node and situated across the stem from each other.
OVATE	-	egg-shaped in outline, attached at the wide end.
PAPILLA	-	a minute nipple-shaped projection.
PAPILLOSE	-	bearing papillae.
PEDICEL	-	the support of a single flower in a cluster, any stalk or stem between sepals and main axis.
PEDUNCULATE	-	having stalk or flower cluster, or of a solitary flower when that flower is the only member of an inflorescence.
PENDENT	-	hanging or declined.
PERIANTH	-	corolla and calyx (not including stigma and stamens).
PETIOLE	-	leaf stalk.
PILOSE	-	covered with long soft trichomes.
PISTIL	-	the seed producing organ, consisting usually of ovary, style and stigma.
PUBESCENT	-	covered with short hairs or trichomes.
SESSILE	-	without petiole or pedicel.
SPOROPHYLL	-	a spore bearing leaf, often highly modified.
STAMEN	-	one of the pollen bearing organs of a flower, made up of filament and anther.
STIGMA	-	the part of the pistil that receives the pollen, usually at or near the pistil and mostly hairy, papillose or sticky.
SUBOPPOSITE	-	nearly opposite.
SUBSESSILE	-	almost sessile.
TOMENTOSE	-	densely woolly or pubescent.
TRICHOME	-	hair-like structure or bristle which may be simple, branched, capitate, and unicellular or multicellular.
UMBEL	-	an inflorescence with pedicels or peduncles (rays) or both arising from a common point.
WHORLED	-	with 3 or more leaves or other structures arranged in a circle around a stem or some common axis.

Photo 1. Whole plant

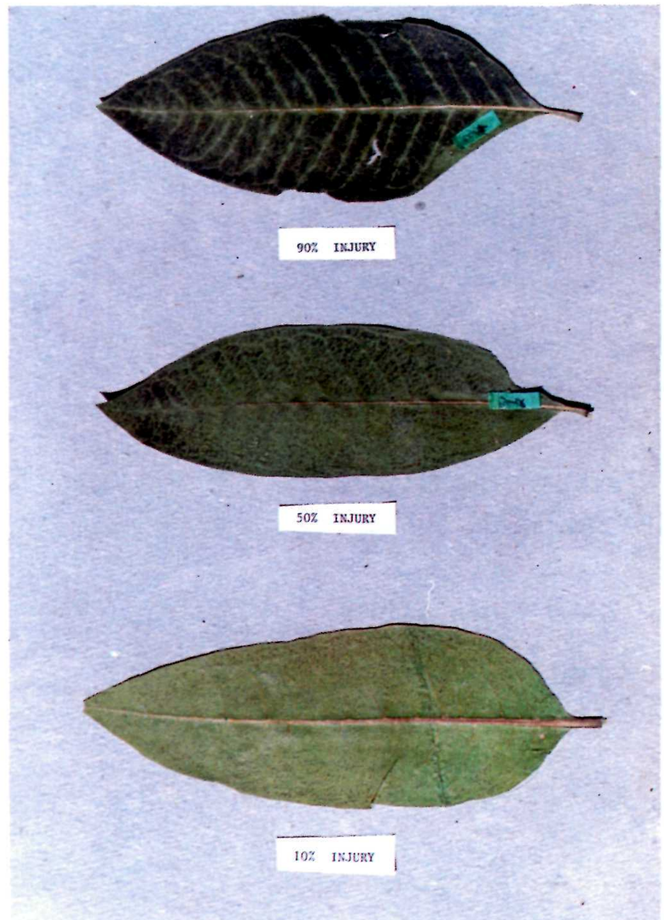
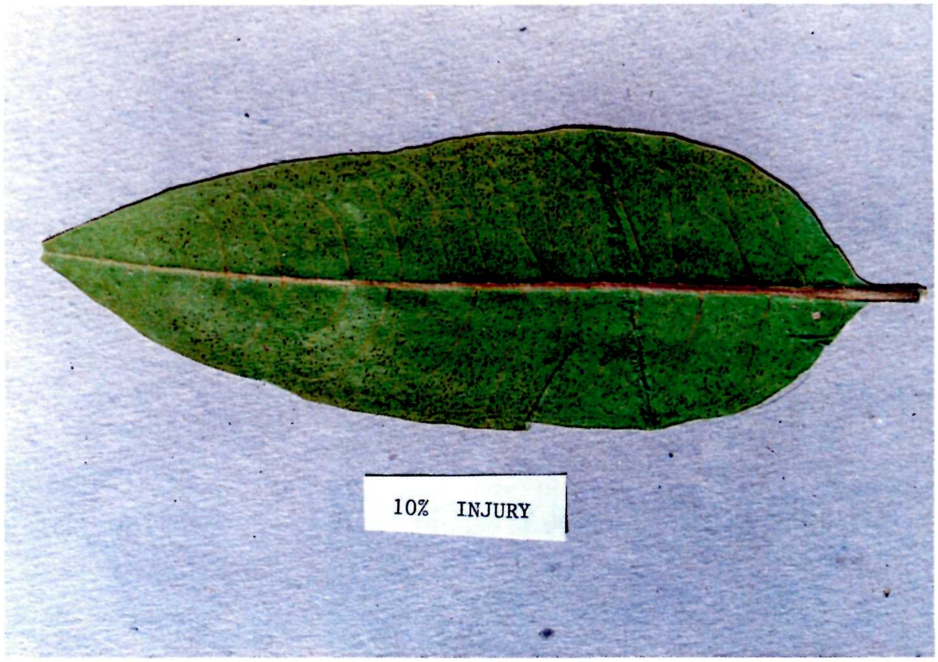
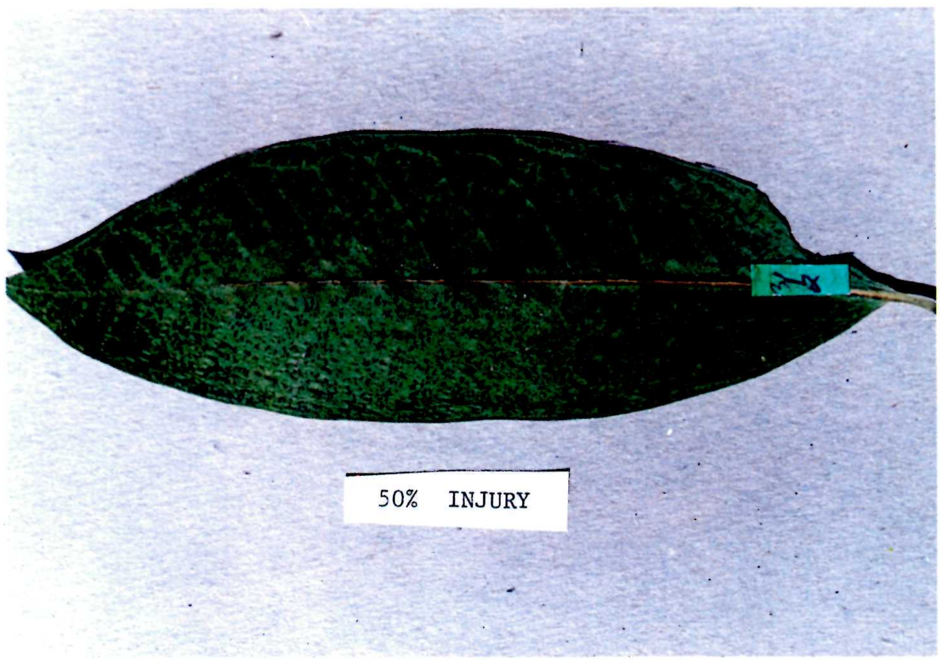


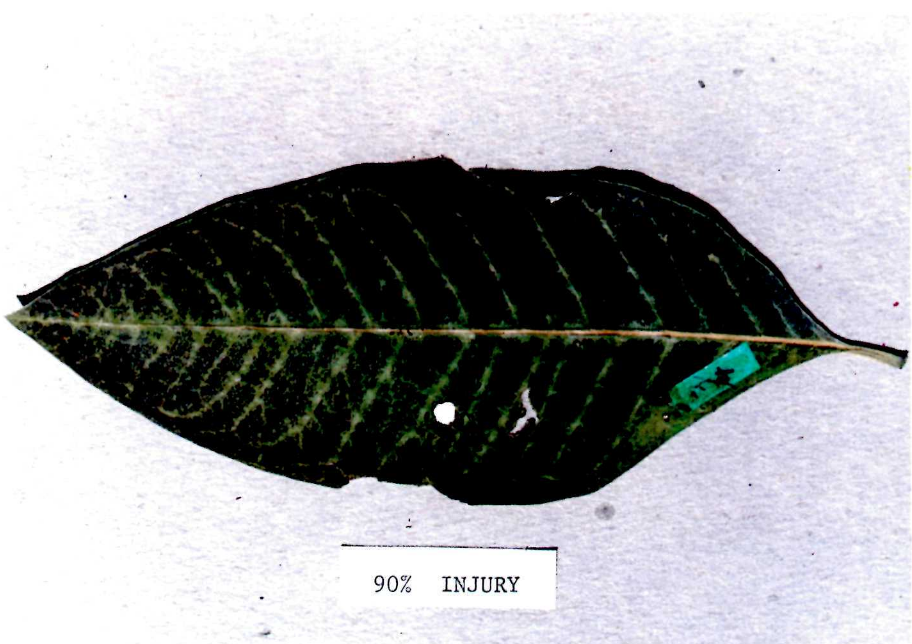
Photo 2. Three levels of ozone injury

<u>Asclepias</u> <u>syriaca</u> (Linn.)

(Common milkweed)





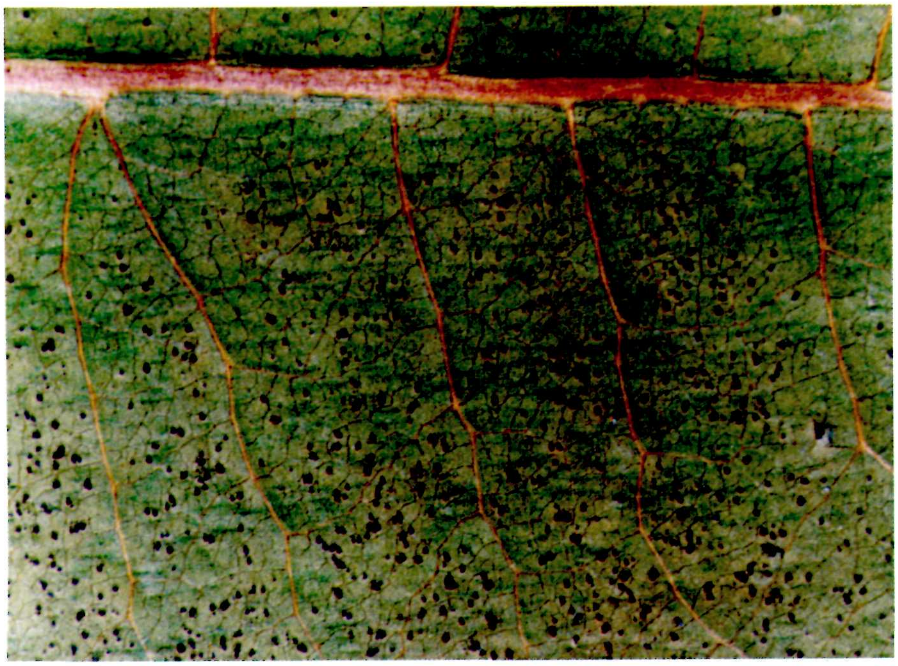


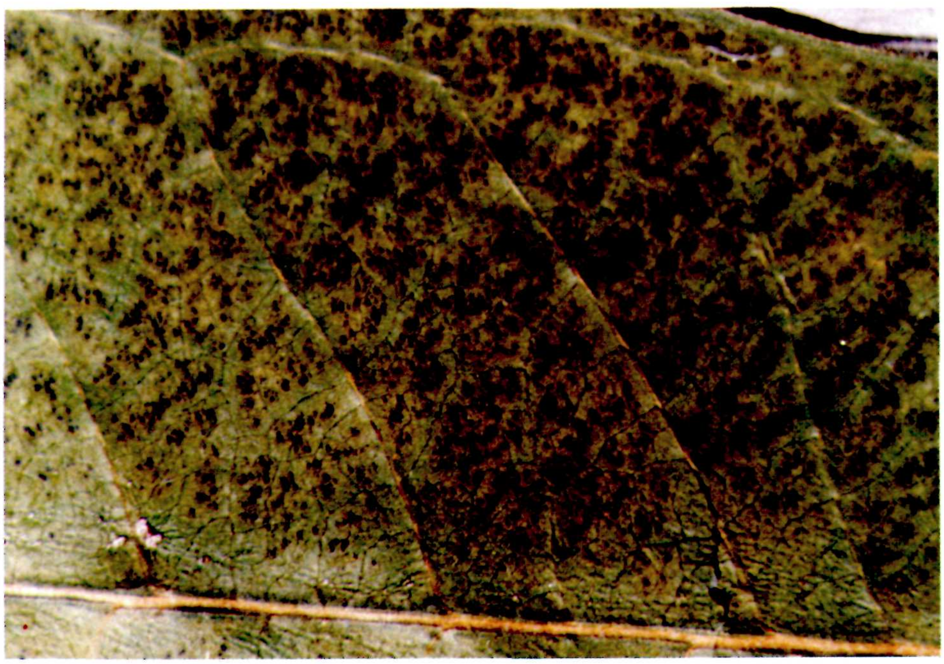
Visible ozone injury on _Asclepias_ _syrica_ L.

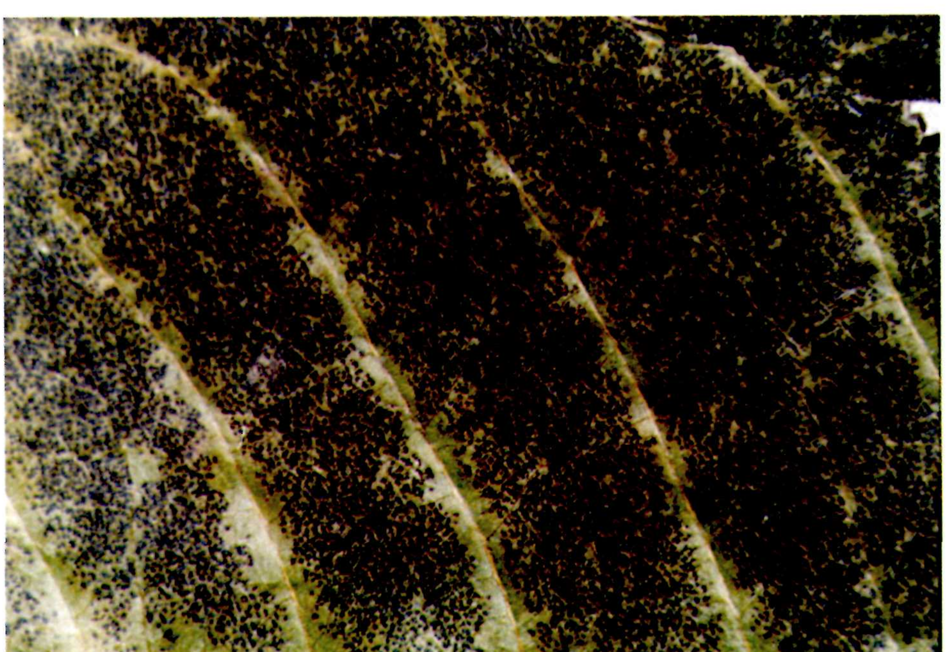
Photo 3 (top)
10% visible injury

Photo 4 (middle)
50% visible injury

Photo 5 (bottom)
90% visible injury







Close-up of visible
ozone injury on
A. syriaca L.

Photo 6 (top)
10% visible injury

Photo 7 (middle)
50% visible injury

Photo 8 (bottom)
90% visible injury

Photo 9. Ozone injury on Asclepias syriaca.
Upper surface visible injury
Lower surface without injury

Photo 10. Monarch butterfly larva (Danaus plexippus) feeding on milkweed plant.

JAMES P. BENNETT, Ph.D. - Ecologist, Research Branch, Air Quality Division, National Park Service, Denver, Colorado.

Jim began doctoral research on air pollution effects on plants in 1970 at the University of British Columbia. He designed and built air pollution greenhouses and fumigation equipment and experimented with exposures of ozone on barley, smartweed, annual ryegrass and crimson clover. This doctoral work was subsequently published and was the first documented work on air pollution affecting plant competition. After this, in 1975, Jim moved to the University of California, Davis, where he became a professor on the Department of Vegetation Crops. He continued air pollution studies by building open-top chambers and chamberless exposure systems for row crops. This work on the combined effects of O_3 and H_2S on bean injury and yield is the only published work of its kind. In total, he has over 15 professional publications in the field of air pollution effects on plants. Jim also began researching the effects of siting power plants in agricultural areas in California, which led to his transfer to the U.S. Fish and Wildlife Service national power plant team in Ann Arbor, Michigan. There he completed projects on manuals for assessing power plant impacts on wildlife and their habitats. When the national power plant team was reorganized, Jim transferred to the National Park Service.

Jim began his National Park Service career in 1981. He initiated a biological effects research program and is responsible for managing the program. He designs biomonitoring projects, injury surveys, trace element surveys, ecological studies, and statistical analyses of data. He has expertise in diagnosing foliar injury from air pollution, and the ecological effects of air pollutants.

Jim has a B.A. in botany from the Missouri Botanical Gardens and Washington University, St. Louis; an M.A. in botany from the University of Michigan, Ann Arbor; and a Ph.D. in plant science from the University of British Columbia, Canada.

KENNETH W. STOLTE - Biologist, Research Branch, Air Quality Division, National Park Service, Denver, Colorado.

Ken first worked for the National Park Service as a seasonal interpreter at Joshua Tree National Monument in the summer of 1979. From 1979 to 1981, he served as a research assistant in plant morphology where he used light and scanning electron microscopy to study the relationship between leaf structure and pollutant sensitivity while completing his graduate studies on the pollutant sensitivity of the chaparral community. From 1981 to 1983, Ken served as a post-graduate research assistant at the California Statewide Air Pollution Research Center where he assisted in a multi-year project to study the movement of air pollutants into the southern Sierra Nevadas and the effects of ozone and sulfur dioxide on forest trees species. In 1983, he took a position with the U.S. Forest Service where he studied the distribution of pollutants in Sequoia National Park and the effects of ozone and sulfur dioxide on pines, black oak and sequoia seedlings. In December 1983, Ken joined the Air Quality Division, where his responsibilities are the design of chamber fumigation experiments and field biomonitoring studies, recognition of pollution injury symptoms, review of proposals and final reports of plant response to pollutants, contract preparation to initiate effects studies and coordination of effects studies for individual parks by serving as liaison between park personnel and scientific researchers.

Ken has a B.S. degree in biology (1979) and a M.S. degree in botany (1982) from the University of California at Riverside.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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