NATIONAL PARK SERVICE
INTERGRATED PEST MANAGEMENT
INFORMATION PACKAGES

SEPTEMBER 1984

PREPARED FOR:

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

United States Department of the Interior

NATIONAL PARK SERVICE
WASHINGTON, D.C. 20240

IN REPLY REFER TO:

SEP 1 9 1984

Dear Reader:

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

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

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

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

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

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

Sincerely,

John C Reed
Chief Biological Resources Division

Enclosures

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NATIONAL PARK SERVICE
IPM Information Package

ANTS

Final Report

30 August 1984

Submitted To:

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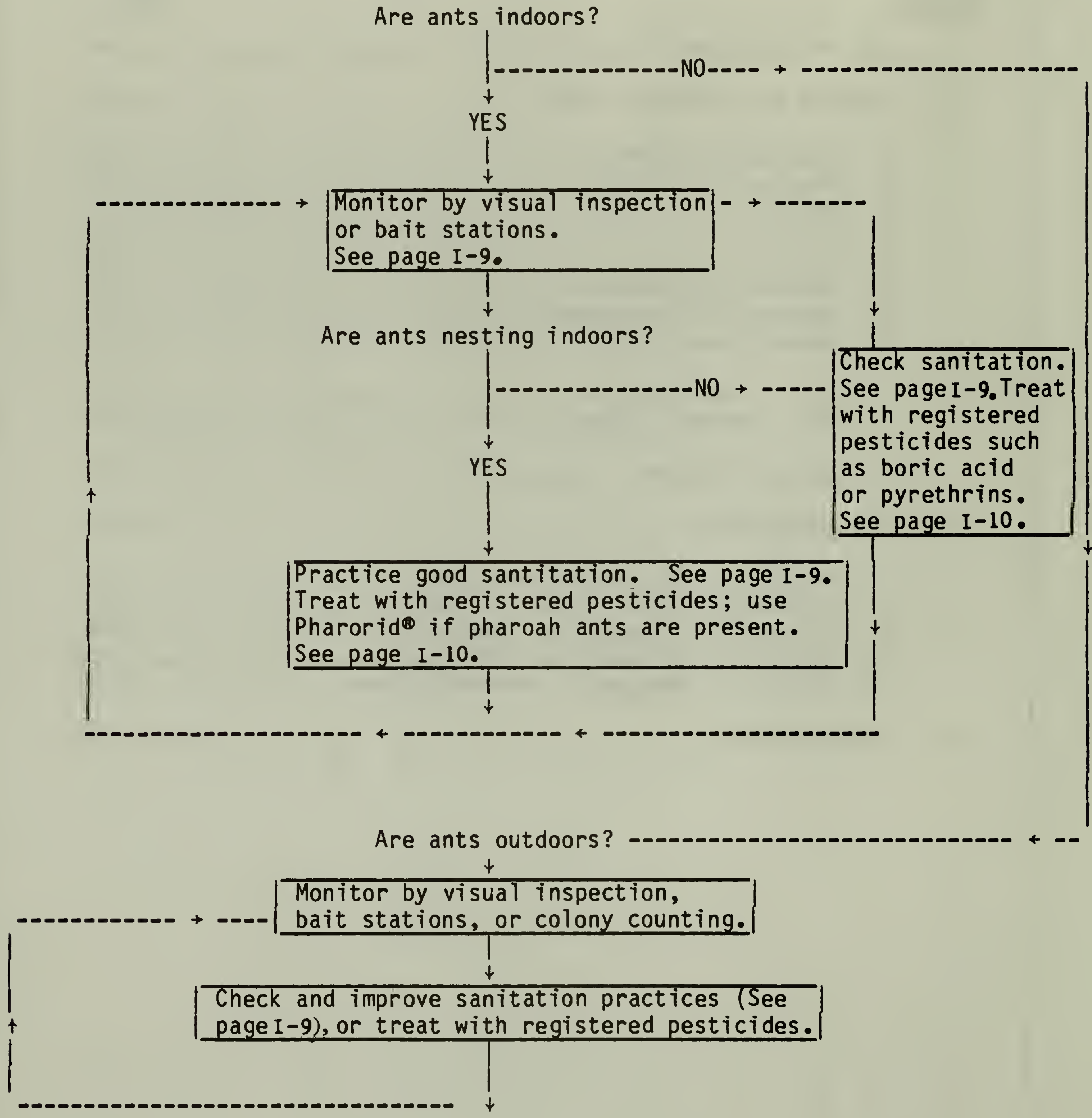
I. ANT IPM DECISION TREE

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



II. BIOLOGY AND ECOLOGY OF ANTS

1. Species Described:

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

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

A. Pavement Ant - *Teramorium caespitum* (L)

B. Thief Ant - *Solenopsis molesta* (Say)

C. Crazy Ant - *Paratrechina longicornis* (Latreille)

D. Field Ants - *Formica spp.*

E. Pharaoh Ant - *Monomorium pharaonis* (L)

F. Argentine Ant - *Iridomyrmex humilus* (Mayr)

G. Harvester Ants - *Pogonomyrmex spp.*

2. Geographic Distribution:

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

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

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

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

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

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

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

3. Habitat:

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

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

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

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

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

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

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

4. Hosts:

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

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

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

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

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

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

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

5. <u>Life Cycles</u>:

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

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

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

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

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

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

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

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

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

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

6. <u>Seasonal Abundance</u>:

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

7. <u>Responses to Environmental Factors:</u>

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

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

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

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

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

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

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

8. Medical Importance:

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

8.1. Direct Effects:

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

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

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

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

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

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

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

8.2. Indirect Effects:

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

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

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

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

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

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

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

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

III. ANT MANAGEMENT

1. **Population Monitoring Techniques:**

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

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

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

2. **Threshold/ Action Population Levels:**

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

3. **Management Alternatives - Nonchemical:**

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

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

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

4. **Management Alternatives - Chemical:**

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

A. Conventional Chemicals

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

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

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

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

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

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

5. <u>Summary of Management Recommendations:</u>

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

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

IV. BIBLIOGRAPHY

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NATIONAL PARK SERVICE
IPM Information Package

FLIES I
(HOUSE, STABLE, FACE)

Final Report

27 July 1984

Submitted To:

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

Submitted By:

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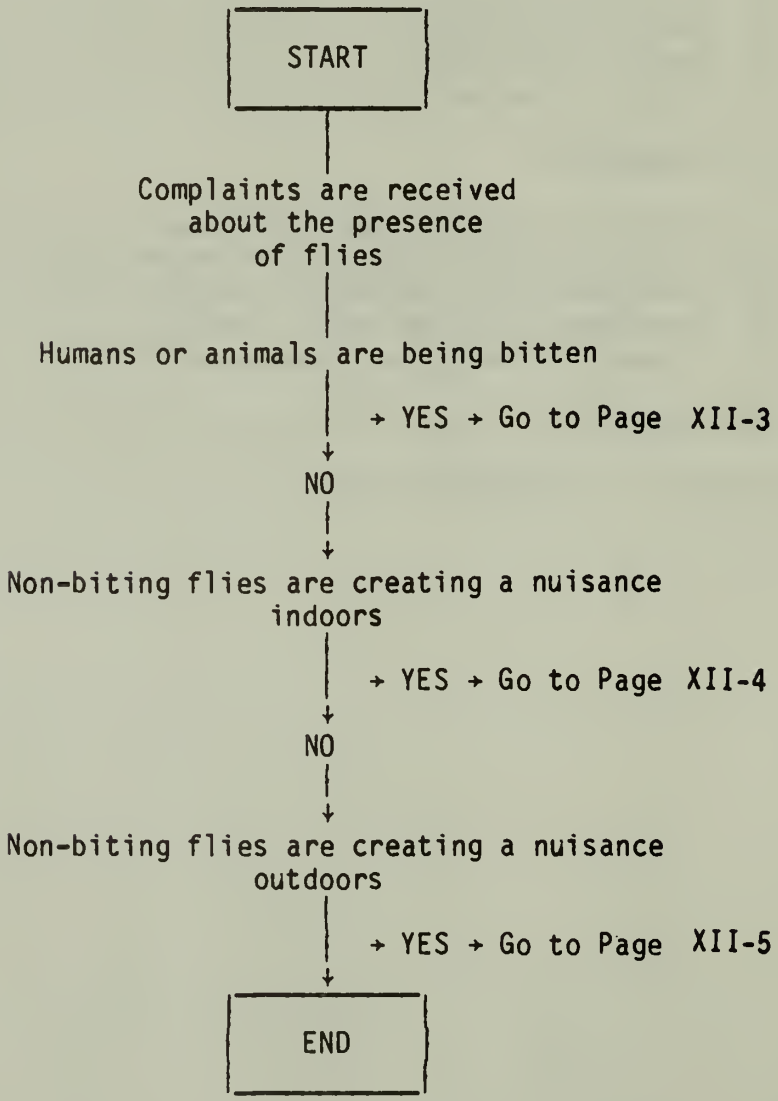
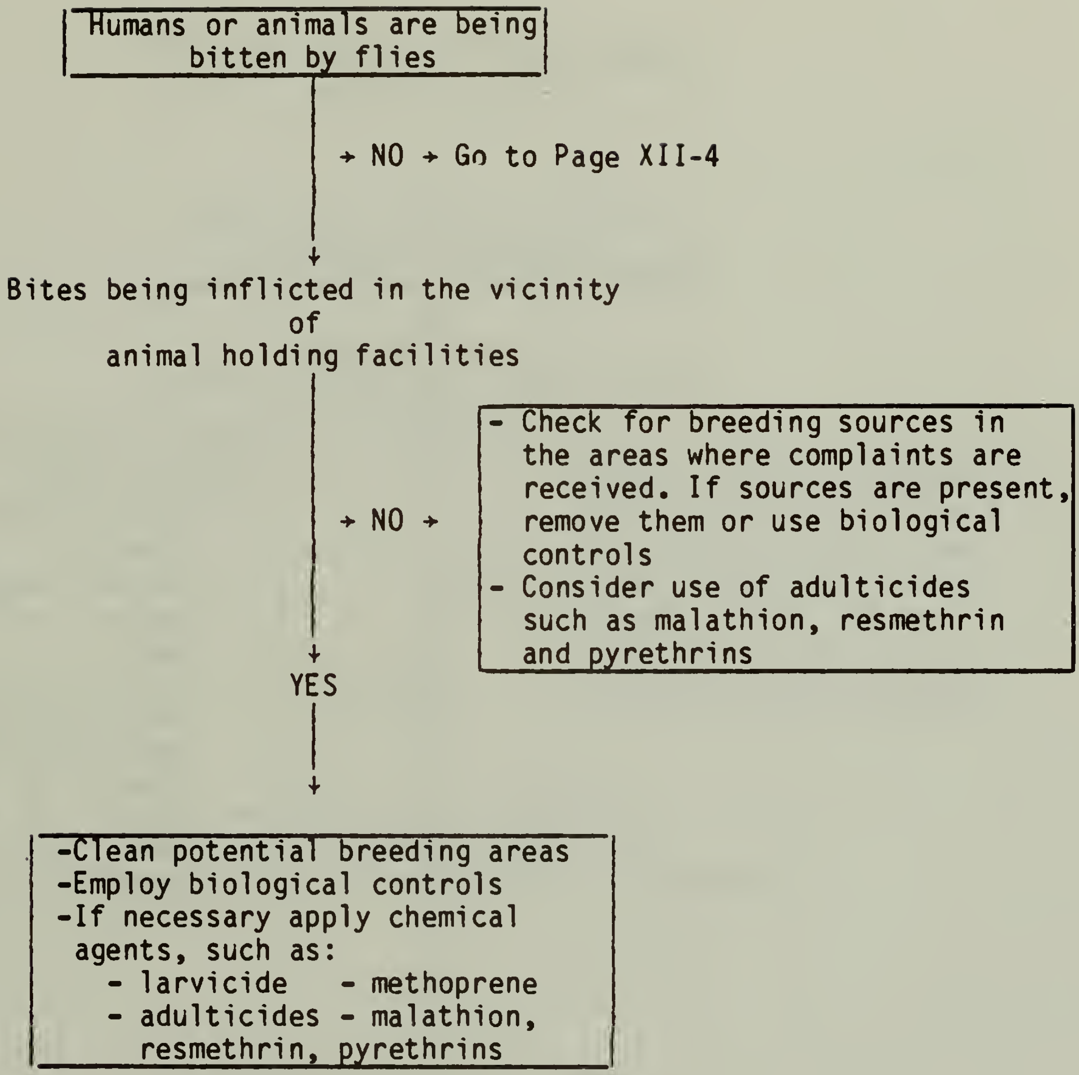
CONTENTS

I. FLY IPM DECISION TREE

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





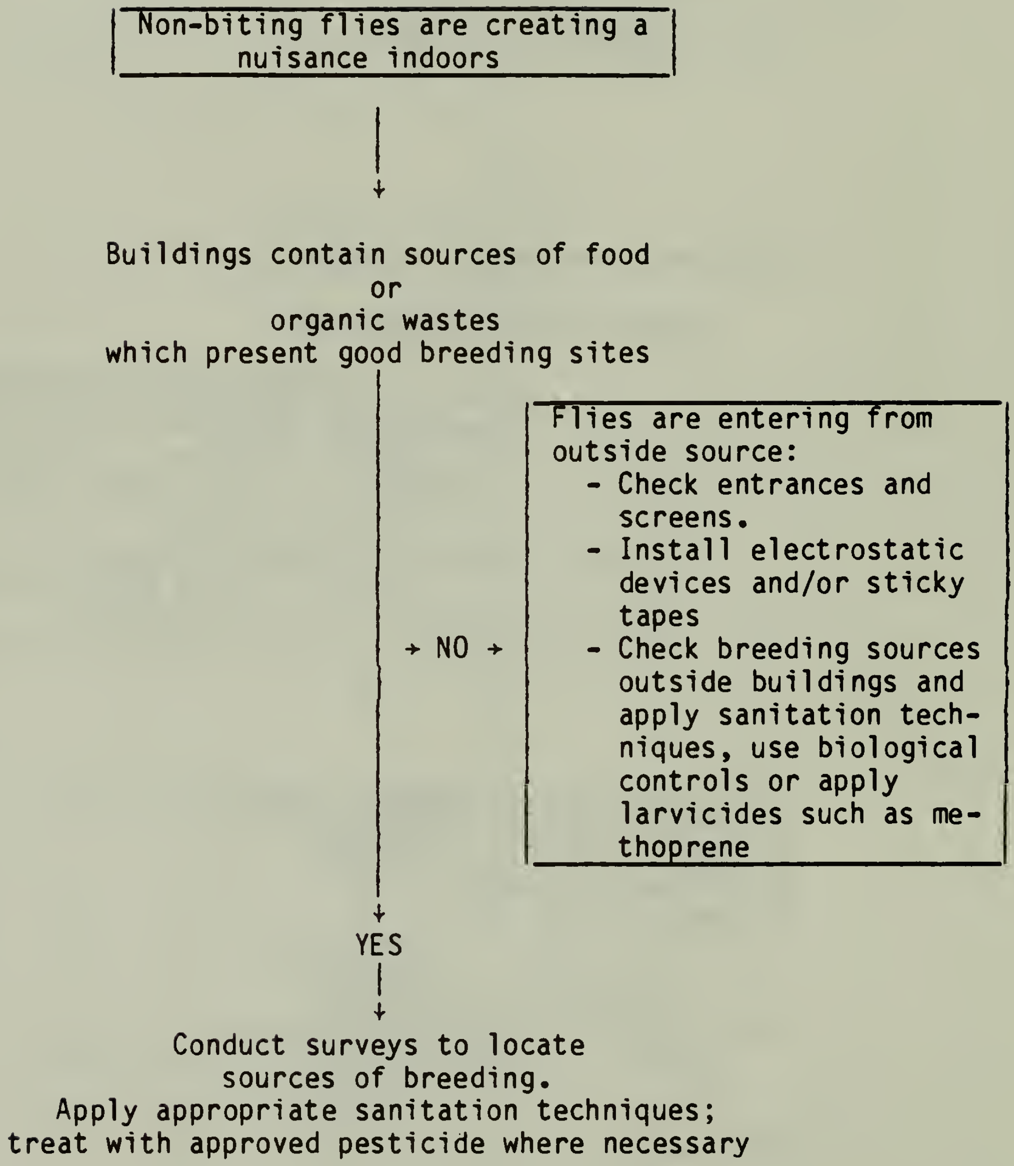
Humans or animals are being bitten by flies

→ NO → Go to Page XII-4

Bites being inflicted in the vicinity of animal holding facilities

- Check for breeding sources in the areas where complaints are received. If sources are present, remove them or use biological controls
- Consider use of adulticides such as malathion, resmethrin and pyrethrins

-Clean potential breeding areas
-Employ biological controls
-If necessary apply chemical agents, such as:
  - larvicide - methoprene
  - adulticides - malathion, resmethrin, pyrethrins



Non-biting flies are creating a nuisance indoors

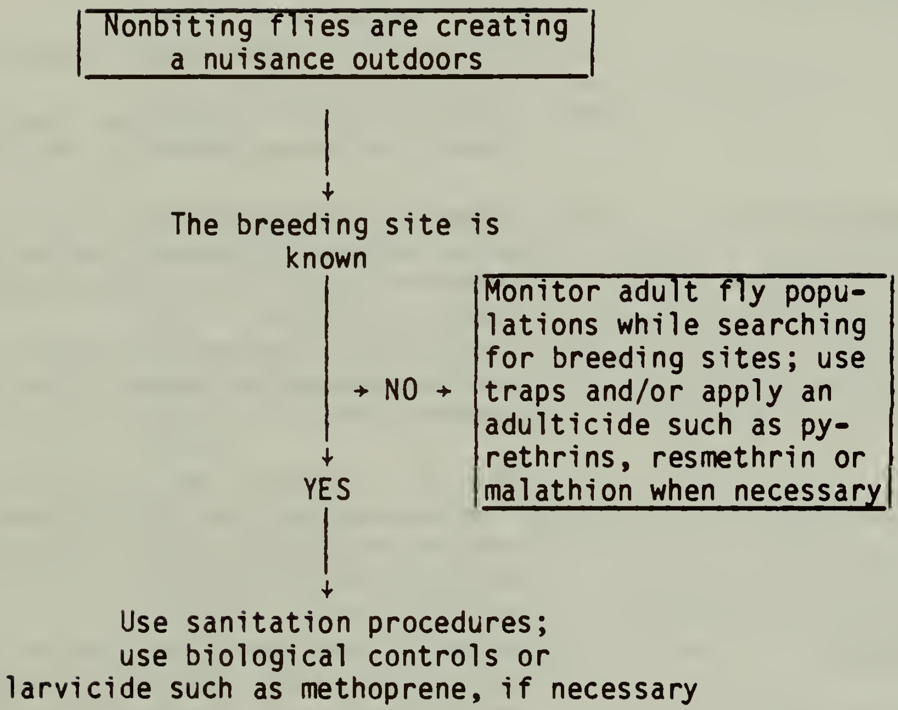
Buildings contain sources of food
or
organic wastes
which present good breeding sites

→ NO →

Flies are entering from outside source:
- Check entrances and screens.
- Install electrostatic devices and/or sticky tapes
- Check breeding sources outside buildings and apply sanitation techniques, use biological controls or apply larvicides such as methoprene

YES

Conduct surveys to locate
sources of breeding.
Apply appropriate sanitation techniques;
treat with approved pesticide where necessary



Nonbiting flies are creating a nuisance outdoors

The breeding site is known

NO

Monitor adult fly populations while searching for breeding sites; use traps and/or apply an adulticide such as pyrethrins, resmethrin or malathion when necessary

YES

Use sanitation procedures; use biological controls or larvicide such as methoprene, if necessary

II. BIOLOGY AND ECOLOGY OF FLIES

1. Species Described:

A. House fly - *Musca domestica* L.

B. Stable fly - *Stomoxys calcitrans* L.

C. Face fly - *Musca autumnalis* DeG.

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

2. Geographic Distribution:

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

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

C. Face fly - The only states free of the face fly are Texas, Louisiana, Florida, New Mexico, and Arizona.

3. Habitat:

A. House fly - House flies may be found in any situation where sources of organic wastes are available. This includes landfills, garbage dumps, barns, etc.

B. Stable fly - Stable flies may be found near livestock or fermenting vegetable matter such as straw, seaweed, grass clippings, etc.

C. Face fly - Females may be found near livestock or livestock droppings. Males feed on nectar of flowers and may be found in pasture margins, wooded areas at pasture edges and fence rows.

4. Hosts:

A. House fly - House flies feed on decaying organic matter. They may be found around manure piles and rotting garbage. They are not blood feeders.

B. Stable fly - Adult stable flies are blood feeders They generally feed on the lower part of the legs of cattle and horses. They may also feed on humans and dogs. Flies only stay on the animal long enough to obtain a blood meal and then seek a shaded place such as a fence or barn wall to digest the meal. They return for additional meals several times a day, but most activity takes place between 7-8 am and 6-7 pm.

C. Face fly - Adult face flies do not have mouth parts capable of piercing the skin of their hosts, so they are not normally blood feeders. Females cause annoyance while feeding on wounds or moist mucus secretions on an animal's face. As noted above, males are nectar feeders and are not attracted to animal secretions.

5. Life Cycle:

A. House fly - The female house fly deposits many eggs in decaying organic matter, such as manure piles and decaying garbage. A female deposits from 100-150 eggs at a time; the eggs hatch under summer conditions in 12-24 hours. The larva develops rapidly and becomes a pupa (nonactive stage) in 15 days, then becomes an adult in 2-4 days. Within 2 days after emerging, adults can mate and 2-3 days after mating, the female can lay eggs. House flies generally overwinter as immature forms or, less commonly, as adults.

B. Stable fly - The female stable fly generally deposits her eggs in decaying organic matter, such as hay or straw. Eggs hatch within 1-4 days and the larvae bury themselves, begin to feed, and mature to adults in 14-26 days. Stable flies can mate several days after maturation. They generally overwinter as immature forms buried deep in straw or manure piles.

C. Face fly - Females lay eggs only in fresh manure; larval development occurs within the manure and in the soil surrounding it. The total cycle from egg to adult takes 8-25 days. Face flies overwinter as adults in barns, buildings or under tree bark.

6. Seasonal Abundance:

A. House fly - House flies can be a nuisance throughout the year. Breeding can take place as long as temperatures are warm enough for flies to be active. Three to seven days of freezing will kill the immature stages. Adult flies are active throughout the winter on warm days and apparently do not hibernate.

B. Stable fly - Stable flies are active during the warm months and are usually found from March to November in temperate zones.

C. Face fly - Face flies are present on cattle and horses from April through October and are present in greatest numbers from July to September.

7. **Environmental Factors Affecting Survival:**

A. House fly - House flies are sensitive to extremes in temperature and humidity. Low humidity and/or high temperatures affect dispersal rates and cause buildup of high populations at major breeding sites. Low humidity may limit ovipositing females to one batch of eggs.

B. Stable fly - Stable flies prefer humid areas with moderate temperatures.

C. Face fly - Face flies prefer high humidity and moderate temperatures.

8. **Medical Importance:**

Flies affect the well-being of man and other animals most significantly by transmitting disease causing organisms. Many of the intestinal diseases of humans are transmitted by flies. Filth inhabiting flies have been implicated as carriers of typhoid fever, dysentery, trachoma, tularemia, cholera, tuberculosis, anthrax, trypanosomiasis, leishmaniasis, diptheria, poliomyelitis and a number of other diseases. In most cases the disease-causing relationship is based on the fact that individual flies will explore large varieties of organic substrates and will move contaminants from one site to another. Various species of flies have been implicated in the transmission of food poisoning organisms such as *Staphylococcus, Salmonella,* and *Streptococcus.* House and stable flies have been implicated in the transmission of several diseases such as mastitis and infectious anemia in livestock, and face flies have been shown to transmit pinkeye in cattle and horses.

Flies can also cause severe annoyance to people and other animals. Stable flies, for example, are vicious biters and may account for serious blood loss in domestic animals. It has been demonstrated that cattle can lose between 1/4 and 3/4 of a pound per day as the result of attacks by biting flies (Campbell and Hermanussen, 1971).

9. **Natural Enemies:**

Flies have many natural enemies ranging from insects to birds. These enemies can attack all stages of the life cycle from egg to adult. Many of these natural enemies can be used to provide biological control (see Section III.3).

III. FLY MANAGEMENT

1. Population Monitoring: Techniques:

Population monitoring is an important part of any fly management program. While thresholds for treatment must be determined for an individual situation (see Section III.2), monitoring programs serve as valuable tools for treatment decisions. A sample fly monitoring form is presented on page XII-20

A. House fly - House flies may be difficult to monitor effectively. However, many trapping methods have been used with some success.

1. Monitoring larvae - Larvae are most often found in decaying animal and vegetable matter. They are commonly found indoors in decaying litter or bedding and outdoors in garbage or manure piles. Among the techniques used for estimating larval populations are: (1) taking a large spoonful of manure from 10 locations in a manure pile, spreading each on a plywood board and counting larvae (Bailey et al., 1970) and (2) placing a known volume of manure in a bucket and collecting pupae by flotation (Hurd et al., 1979).

2. Monitoring adults - The adult house fly can be monitored by several methods, depending on the location. In buildings, sticky fly tapes can be hung from ceilings over areas frequented by flies. However, the usefulness of these tapes is limited because the tape may lose its effectiveness in 1-2 days. In outdoor situations the tapes soon dry out. Some workers have used paper plates smeared with adhesive for trapping flies. Some workers estimate fly populations using a Scudder grill; this grill, 1 m^2, is placed on the ground and the number of flies landing on it in a specified time period, such as ten minutes, is counted and recorded.

   If electricity is available, a fly trap with a UV lamp can be an effective monitoring device. An inexpensive, low maintenance UV lamp has been described by Thimijan et al., 1970; it is constructed of plywood, aluminum screenings, and a bulb. The lamp is sensitive to small changes in populations and captured flies remain in excellent condition for identification. Two traps per medium sized enclosure (e.g. 3,000 ft^2) should be sufficient.

Baited fly traps can also be used as a monitoring device. The Dodge trap (Morgan and Pickens, 1978) is easy to construct; it consists of a carton, a screen cone and a bait source. Flies are drawn to the organic bait and become trapped in the carton. They may be counted on a daily or weekly basis.

B. Stable fly - The techniques described above may also be used to estimate stable fly populations. Another technique described for adults of these insects is a trap consisting of two fiberglass (Alsynite) panels (28 x 45 cm) that are interlocked at right angles and mounted 50 cm above the ground on a stake (Williams, 1973). The panels are treated with an adhesive material. The trap has been highly effective in density assessments when positioned in fly-ways, breeding areas and resting sites.

Treatments for stable fly control have been assessed by counting the number of flies present on a "bait" animal for a given length of time. However, the time of day when observations are made is very important because most feeding activity by stable flies occurs at 7-8 am and 6-7 pm.

C. Face fly - A modification of the stable fly trap may be used to estimate face fly populations. A 4-sided fiberglass diamond, painted white and coated with adhesive, is hung from the barn ceiling where it attracts face flies.

Another technique for estimating face fly populations is counting the number of flies found on the faces of several animals per specified unit of time (such as the number of flies/5 minutes).

2. Threshold/Action Population Levels:

Thresholds for fly control treatments will vary with the situation. Every effort should be made to correlate fly populations observed through the use of monitoring techniques with complaints received from park visitors and personnel. In this way, a complaint threshold level can be established for each park site.

A. House fly - When sticky traps were used as monitoring devices, Morgan and Pickens (1978) reported that 50-75 flies/trap/day indicated a moderately heavy population. With UV light traps, collection of 150-200 flies/trap/night indicated a heavy population and with baited traps, 300-400 flies/trap/day indicated a heavy population.

B. Stable fly - The number of flies feeding on a particular animal has not been correlated with the total population of flies at a particular site. However, Morgan and Pickens (1978) suggest that each fly found on an animal during peak feeding periods probably represents 50 flies in the total population. The annoyance factor at the site is the most critical indicator for treatment.

C. Face fly - Since the face fly is not as responsive to baited or light traps as other flies, visual counts are recommended. More than 10 flies per animal face per 5 minutes is an indication of a heavy population (Morgan and Pickens, 1978).

3. Management Alternatives-Non-chemical:

A. House fly

1. Habitat modification - Basic sanitation requires the most effort in terms of manpower but is the most effective way of dealing with pest flies. Breeding places for flies should be eliminated as a first step. Garbage in buildings and recreation areas should be properly stored. Containers with tightly fitting lids should be used for storing food wastes and the containers should be thoroughly cleaned when the food and other garbage is removed. Waste waters from cleaning processes should be channeled into sewers rather than being permitted to run into the ground. Garbage should be properly disposed in an approved sanitary landfill.

For stables and other animal holding facilities, special precautions should be taken. Since manure is a preferred medium for fly egg deposition, these areas should be cleaned frequently and residues discarded in a sanitary manner. Manure turning or spreading aids in drying manure piles and discourages egg deposition. Paved animal runs should drain into sanitary sewers.

To keep adult flies from entering residences, recreation buildings, and food handling establishments, all doors and windows should be supplied with closely fitting screens. These should be routinely inspected for rips or tears. The screens may be supplemented by air screens at entrances, sticky fly tapes or fly traps for more effective control.

Devices which will kill some flying insects, including flies, are manufactured by several companies. Insects are attacted to an ultraviolet bulb which is surrounded by a screen with an electric charge. When the fly contacts the screen, it is killed and its remains drop into an area accessible for easy cleaning.

2. Biological control - A number of parasites may be used to lower the density of fly populations at a given site. The parasites most effective are species of *Spalangia* and *Muscidifurax.* These wasp parasites feed and reproduce on immature flies and destroy them. The parasites are harmless to humans and most other insects.

   Commercial insectaries, such as Agricultural Insect Management in Grady, AL, sell these parasites for fly control. The number and species of parasites which should be released varies with the site and situation. Instructions from the supplier of the parasites should be consulted for details. Mass releases are often quite effective when fly populations are high; they may have little effect when densities are low.

   A number of mites have been shown to be predaceous on house flies. *Macrocheles muscaedomestica* (Scopoli) and *Fuscuropoda vegetans* (De Geer) attack the eggs and larvae of houseflies and little house flies. Wicht and Rodriguez (1970) investigated the use of predatory mites, a larvicide that would be harmless to mites,and a poison bait for adult houseflies. Fly populations were reduced to approximately 35% of their pretreatment level in 3 weeks.

3. Sterility induction programs - Chemosterilants have been investigated for a number of years as a means of fly control. Many chemicals have been examined for their ability to sterilize male flies. Pausch (1971, 1972) tested the chemosterilant activity of six substances: apholate, hempa, metepa, tepa, tetramine, and triphenyltin hydroxide.

   In laboratory tests, hempa, metepa, and tepa induced a high degree of sterility in flies after exposure for 3 days to the chemosterilants. Fly populations in an enclosed barn showed sterility levels of >80% after 4 weeks of exposure to chemosterilants. In 7 weeks the population was so low that few flies could be captured.

   While a number of these types of sterility induction programs have been carried out experimentally, the technique has not yet proven to be effective in practical situations.

B. Stable fly - Those control measures listed for house flies can also be effective in controlling stable flies. In addition, laboratory tests have shown that the stable fly is suceptible to the pathogen <u>Bacillus thuringiensis,</u> although levels needed for control are high.

C. Face fly - See 3.A. for management techniques. The face fly may also be infested by a nematode <u>Heterotylenchus autumnalis</u> which effectively makes the female incapable of laying eggs. Some attempts at rearing and releasing the nematode have been made but much work remains to be done in this area.

4. <u>Management Alternatives - Chemical:</u>

A. House fly

While several chemicals for fly control are mentioned in the following sections, the NPS Regional IPM Coordinator should be consulted to determine which pesticide, if any, is best suited for a particular fly control problem.

1. <u>Larvicides</u> - Larvicides, such as malathion, dimethoate or dichlorvos, are employed less frequently than adulticides for fly control since breeding sites are often far from the "damage site" and may be more difficult to treat. The high organic content of larval sites reduces the effectiveness of some pesticides, and larviciding also encourages the accelerated development of insecticide resistence. In a study investigating fly control in poultry houses (Axtell, 1970b), 16 to 18 applications of pesticides were needed during the course of the season for satisfactory fly control. Manure inhabiting mites, which prey on larvae, were destroyed in the course of larviciding.

Insect growth regulators (IGR's) such as methoprene do not kill fly larvae but prevent them from developing into adults. IGR's are applied to filth sources where eggs would be expected to be laid. IGR's can be very effective as a component of a total larval control program.

2. Adulticides

a. For control of adult flies within buildings, insecticide emulsions or suspensions may be applied to exterior surfaces on which flies rest. Compounds such as pyrethrins and resmethrin are commonly applied to run-off. In outdoor situations where appearance is not a critical factor, the addition of 1 lb of sugar/gal attracts flies and increases the effectiveness of the treatment. Treatments are only temporarily effective because of the low residual activity of these compounds.

b. Space sprays with resmethrins or pyrethrins may be used for spot treatment inside buildings, but frequent retreatment is necessary. They are even less effective outdoors and must be repeated at least daily where flies are a problem.

c. Adults may also be controlled by means of poison baits. A bait of sugar and molasses, to which toxicant is added, was once widely used but it has been replaced by fermenting protein baits. The baits contain yeast hydrolysate or corn protein with malathion, dichlorvos, diazinon or naled as the toxicant (Metcalf and Flint, 1962). Bait stations must be cleaned frequently, usually once per week, or the contents can become so heavily clogged with dead flies that contact with the bait is impossible (Anon., 1971).

d. Slow release plastic formulations of pestides have been used experimentally. Bailey et al., (1971) applied several pesticides formulated in resins which were then ground to powders or beads and applied to the floors of barns. Three applications of slow release formulation of dichlorvos controlled adults for about 7 weeks. Bennett and Runstrom (1979) showed that encapsulated resmethrin formulations were effective in controlling houseflies even after 3 months.

Hanging fiberglass strips have been shown to be attractive to house flies. When permethrin-treated strips, suspended by cords, were used in swine and calf barns, house fly populations were reduced by 75%.

B. Stable fly - A number of chemicals are used for control of stable flies including pyrethrins, resmethrin and malathion. As noted above for house flies, both larvicides and adulticides may be used. Sprays have been applied directly to animals in some studies but these lost effectiveness in relatively short periods of time.

Attractants may also be used in combination with pesticides for stable fly control. Williams (1973) designed a trap for survey studies which was made of fiberglass panels (coated with an adhesive) which appeared to be attractive to stable flies. Meifert et al. (1978) coated non-sticky panels with permethrin and found that the units removed more than 30% of the stable flies in a cattle yard when they were used at a rate of 1 unit/5 animals.

C. Face fly - See Section 4.A.

5. Summary of Management Recommendations:

A. House fly - Site management is a very important aspect of fly control. Breeding sites should be eliminated by properly disposing of animal wastes and garbage. Containers for food wastes should be tightly closed and cleaned frequently. Moisture control for waste containers (i.e. proper drains for dumpsters) should be carefully observed. Wastewater from food establishments and stables should be channeled into sewers, rather than be allowed to run into the ground. Appropriate approved landfill practices should be observed.

Doors and windows of buildings should be tightly screened and fly traps and/or sticky tapes used where they would be useful. Electrostatic insect killing devices should be used where appropriate. Air screens at loading entrances, especially in warehouses and food handling establishments, should be investigated.

Fly populations should be monitored to determine when nonchemical or chemical treatment may be necessary. Correlating population densities with complaints from park visitors and personnel is essential.

Biological controls should be used when appropriate. Release of larval parasites alone or in conjunction with fly larvicides, adulticides or traps should be investigated as a control measure in areas where fly breeding is a problem.

Conventional chemical controls may be used when other methods are not effective. When considering this alternative, breeding sites should be identified and registered larvicides should be used only when necessary. Care should be taken to use pesticides so that development of resistance is not encouraged. This involves use of pesticides as infrequently as possible and also requires frequent rotation of products. Those pesticides least harmful to mites and non-target insects should be used. Consult with NPS pest management staff to determine which pesticide, if any, is best suited for your fly management program.

B. Stable fly - See 5.A. House fly.

C. Face fly - See 5.A. House fly.

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V. SAMPLE FLY MONITORING FORM

Date:__________ Area:__________ Recorded by:______________________________________

Sketch map of survey area:

N
W--|--E
S

- Indicate type of survey conducted:
  ___ Trapping
  ___ Observation
  ___ Other
- Indicate trap locations, if appropriate
- Include any areas considere especially important such a landfills, kennels, stables etc.

Survey results:

1. Details of method (type of observation, time of observation, etc.)

2. Fly count:

   Species #/________(time)

3. Proposed treatment

4. Date treated ________________ Treated by:_____________________________________

5. Comments

NATIONAL PARK SERVICE
IPM Information Package

GERMAN COCKROACH

Final Report

February 1984

Submitted To:

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

Submitted By:

John Muir Institute
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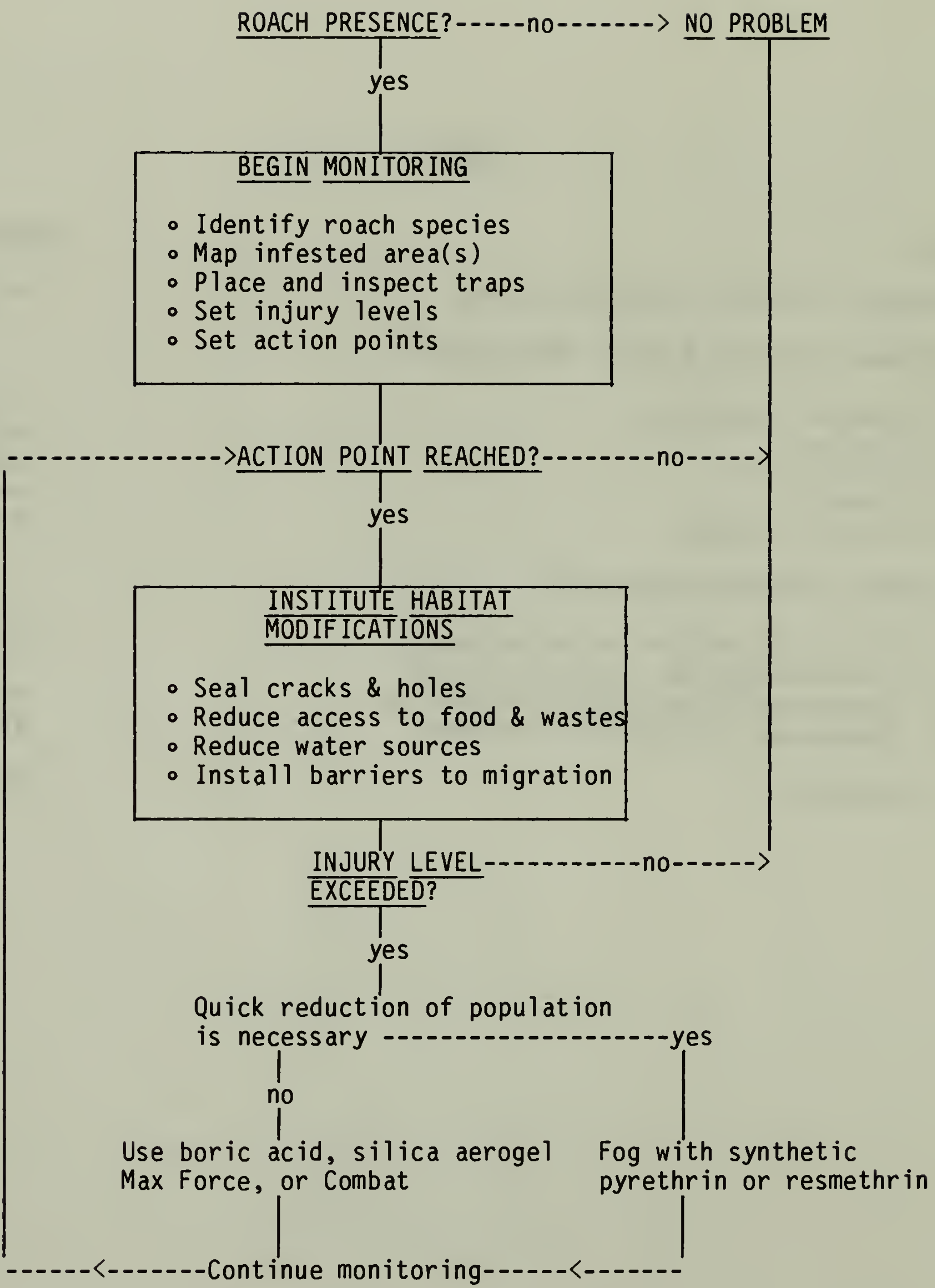
I GERMAN COCKROACH IPM DECISION TREE



II GERMAN COCKROACH BIOLOGY AND ECOLOGY

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

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

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

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

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

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

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

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

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

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

TABLE 1

HUMAN PATHOGENS POSSIBLY ASSOCIATED WITH COCKROACHES*

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

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

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

TABLE 2.

A SUMMARY OF THE KNOWN IMPORTANT PARASITOIDS

OF DOMESTIC COCKROACHES*

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

* Note:

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

II GERMAN COCKROACH MANAGEMENT

1. Population Monitoring Techniques:

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

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

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

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

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

TABLE 3

A COMPARISON OF VARIOUS COCKROACH POPULATION SAMPLING SYSTEMS*

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

* Based on Owens and Bennett, 1983.

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

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

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

TABLE 4

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

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

---

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

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

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

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

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

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

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

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

2. <u>Action/Threshhold Population Levels</u>:

The injury level occurs when the pest population has reached a size large enough to cause intolerable aesthetic, structural or medical damage to the resource. Unfortunately, there is virtually no literature to guide pest control personnel in objectively assessing the type, amount or degree of injury from cockroach presence. The severity of the particular problem may be determined by placing any particular situation in one of the following categories of injury (listed in ascending order of severity):

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

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

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

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

3. Management Alternatives-Non-Chemical:

Indirect supression strategies and tactics are those that change the conditions that create or define the pest problem.

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

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

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

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

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

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

Cockroaches are thigmotactic, i.e. they prefer to have their bodies in touch with a substrate. They favor sites such as cracks where both the upper and lower surfaces of their body are touching some part of the microenvironment. Such sites are commonly found inside buildings with poorly finished construction details or in deteriorating structures. The adult GC can hide in cracks as small as 0.06 inch wide. First instar larvae can squeeze through a gap as small as 0.04 inches (Guthrie and Tindall 1968). To reduce the carrying capacity of the microenvironment such harborage should be caulked or sealed whenever possible.

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

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

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

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

In older dwellings with many cracks, crevices, and hard-to-reach places, start by caulking where highest population levels are located. Every foot of hiding place plugged up reduces the number of cockroaches a structure can support for as long as the plug lasts.

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

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

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

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

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

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

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

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

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

4. <u>Management Alternatives-Chemical</u>:

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

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

TABLE 5.

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

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

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

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

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

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

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

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

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

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

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

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

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

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NATIONAL PARK SERVICE
IPM Information Package

GYPSY MOTH

Final Report

2 August 1984

Submitted To:

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

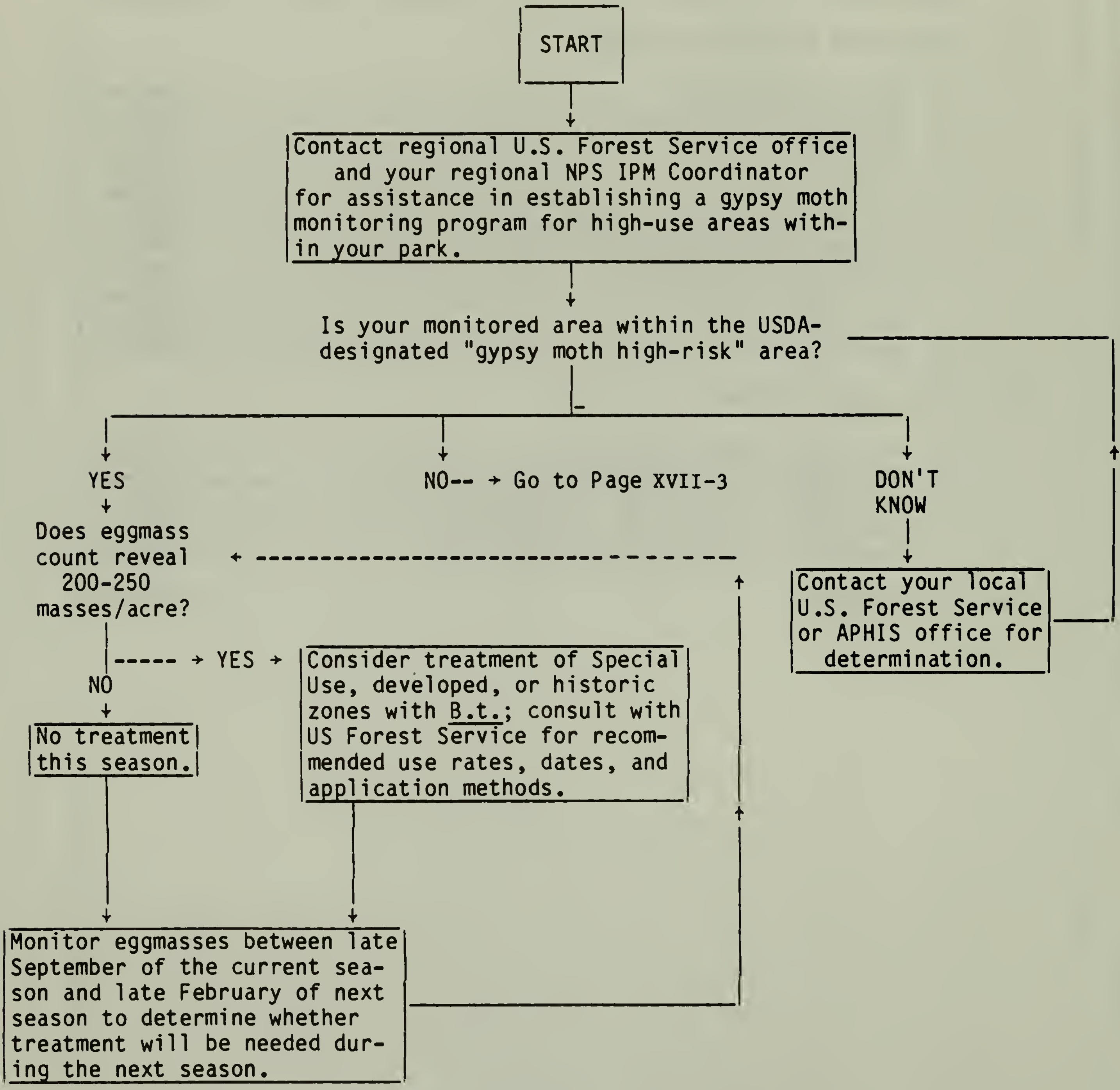
Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

CONTENTS

I. GYPSY MOTH IPM DECISION TREE

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



Contact regional U.S. Forest Service office and your regional NPS IPM Coordinator for assistance in establishing a gypsy moth monitoring program for high-use areas within your park.

Is your monitored area within the USDA-designated "gypsy moth high-risk" area?

NO-- → Go to Page XVII-3

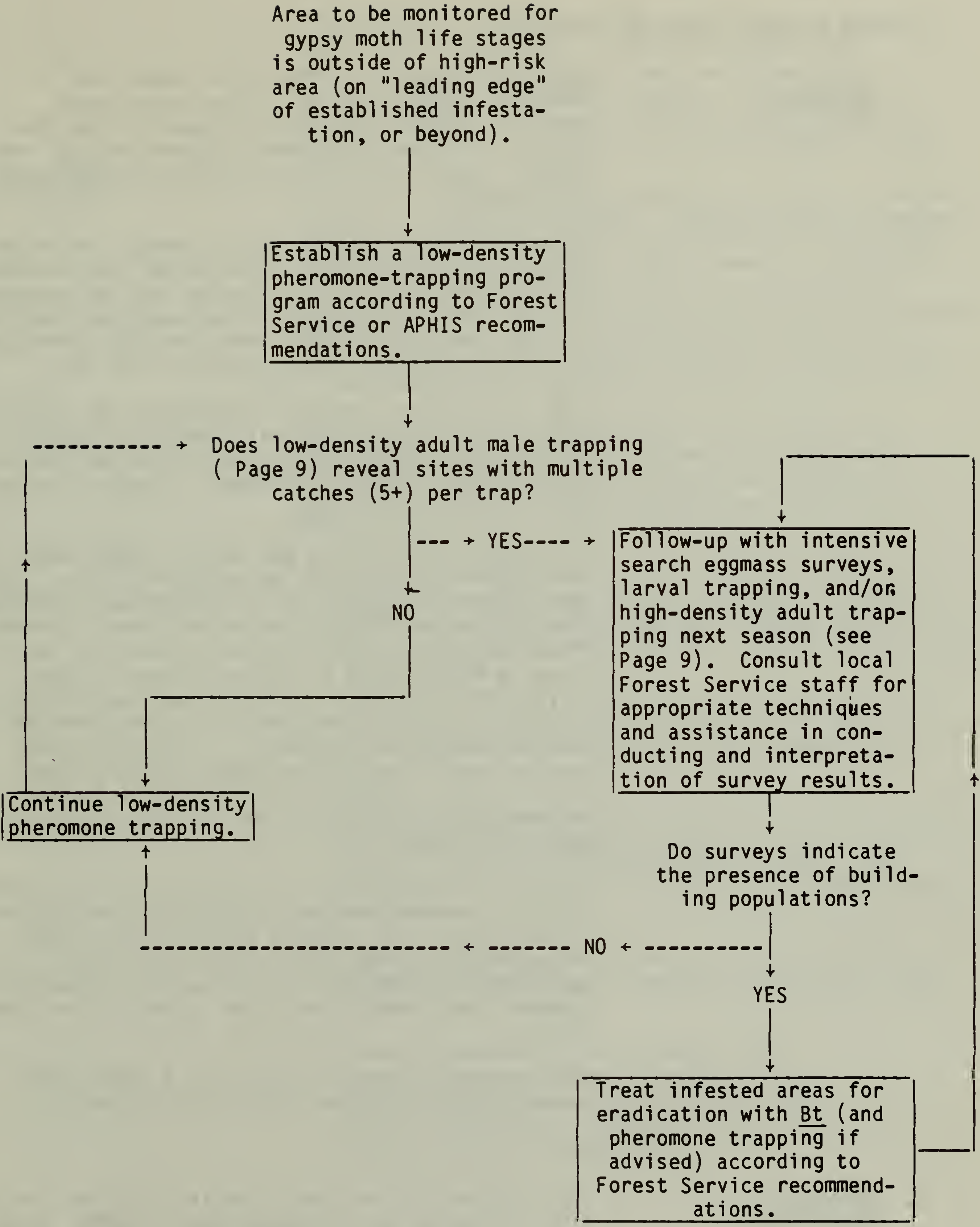
Contact your local U.S. Forest Service or APHIS office for determination.

Does eggmass count reveal 200-250 masses/acre?

Consider treatment of Special Use, developed, or historic zones with B.t.; consult with US Forest Service for recommended use rates, dates, and application methods.

No treatment this season.

Monitor eggmasses between late September of the current season and late February of next season to determine whether treatment will be needed during the next season.


Area to be monitored for gypsy moth life stages is outside of high-risk area (on "leading edge" of established infestation, or beyond).
Establish a low-density pheromone-trapping program according to Forest Service or APHIS recommendations.
Does low-density adult male trapping (Page 9) reveal sites with multiple catches (5+) per trap?
YES
NO
Follow-up with intensive search eggmass surveys, larval trapping, and/or high-density adult trapping next season (see Page 9). Consult local Forest Service staff for appropriate techniques and assistance in conducting and interpretation of survey results.
Continue low-density pheromone trapping.
Do surveys indicate the presence of building populations?
NO
YES
Treat infested areas for eradication with Bt (and pheromone trapping if advised) according to Forest Service recommendations.

II. BIOLOGY AND ECOLOGY OF GYPSY MOTH

1. Species described:

Lymantria dispar (L). The adult female moth is dirty-to-creamy white, with faint and/or dark bands across the forewings. Wingspan varies from 2 to 2 1/2 inches. The female's body is stout and densely covered with hairs, and her antennae appear thread-like.

The male is much darker than the female; the wings are dark brown with black bands across the forewings. The wingspan is about 1 1/2 inches, and the antennae are feathery. The abdomen is narrower than the female' Although the wings of both sexes are fully developed, female gypsy moths fly very rarely, if at all.

Eggs are globular, whitish, and about 1 mm in diameter. They are laid in oval clusters of 75 to 1,000 (averaging 400-500), covered with buff-colored hairs from the female's abodomen. Clusters may be 1/2 inch to 2 inches long.

Fully-grown caterpillars may be 2-3 inches long. The basic color is a buff-yellow to brown or gray. Each body segment has 6 knoblike protuberances (tubercles). The five frontmost tubercles on the dorsal surface of the larva are blue; those behind are red. Each tubercle is topped by a tuft of yellow or brown hairs, which may be up to half a body-length long. A yellow line runs along the top surface from the head to the last body segment. The dark-colored head has additional yellow lines. The true legs are dark red. Younger instars (1-4) are similar in appearance to older larvae, but have proportionately longer body hairs.

Pupae are teardrop-shaped, chocolate to dark red-brown in color, and are rounded in the front and tapered in the abdomen. Male pupae are 2/3-1 inch long, while females may be up to 1 1/3 inches long. A few hairs may occur on the head and each abdominal segment. Each pupa is enclosed in only a few strands of silk.

See McManus and Zerillo (1978) for a photographic guide to all life stages of the gypsy moth.

2. Geographic Distribution:

The gypsy moth is an exotic species which was accidentally introduced into Massachussetts in 1869. Since then, it has spread throughout New England (excluding northern Maine) to many areas in New York; most of

Pennsylvania, Delaware and Maryland; central Michigan; and all of New Jersey. Scattered infestations have been reported in North and South Carolina, Ohio, Alabama, Tennessee, Indiana, Illinois, Wisconsin, Minnesota, Arkansas, California, Oregon, and Washington (Gary Moorehead, personal communication).

3. Habitat: Temperate and boreal deciduous forests are the favored habitats of Lymantria dispar. Damage is often greatest under open forest canopies (where there is relatively little undergrowth) and at forest edges. High population densities (or transport as a result of human activities) may result in migration to nearby or distant softwood forest, urban, and/or agricultural environments, all of which may support gypsy moth populations on available plant foliage.

4. Hosts: The leaves of more than 500 species of trees and other plants are eaten by gypsy moth larvae (adults do not have fully-developed mouthparts, and are not believed to eat). Trees can be grouped according to their suitability as gypsy moth hosts:

a. Trees favored by all instars include alder; all oaks; gray and river birch; basswood; all willows, poplars, apples, all hawthorns; and box elder. Oaks, especially white oak, are considered the most favored foods.

b. Trees fed on by all instars, but not as likely to suffer complete defoliation, include paper birch and larch.

c. Trees fed on (but not favored) by all instars, and suffering only light defoliation, include: all maples, yellow and black birch, all elms, sassafrass, all hickory, black gum, black cherry, and hornbeam.

d. Trees favored only by older larvae include all pines, all hemlocks, all beeches, all spruce, and southern white cedar.

e. Trees unfavorable to all larvae (thus nearly immune to attack) include all ash, butternuts, locusts, dogwoods, American holly, balsam fir, sycamores, tulip tree, red cedar, and black walnut.

Trees under stress (e.g., drought) are attacked more than are healthy trees, and the largest gypsy moth outbreaks are correlated with periods of below-average summer rainfall.

5. Life cycle:

Only one generation of gypsy moths is produced each year. Adults usually emerge from pupae during July, but if populations are high, emergence can be earlier. Males usually appear 1-2 days prior to females. Males fly in zig-zag or (less commonly) straight patterns and are attracted to vertical objects such as tree trunks, where they might find females. Most males will fly less than 1 mile (usually less than 200 meters) from the site of their emergence from the pupae. Females are not known to fly.

Several hours after emerging, females release a sex pheromone (from abdominal glands) in "bursts." Males are attracted to this chemical, and follow the odor trail (and visual cues, within 1-3 yards) to land along-side a receptive female. Mating may last up to 1 hour, after which females begin depositing eggs. Multiple mating is common among males, but rare among females, since the release of the pheromone is inhibited by mating. Adult moths live about 1 week.

Most eggs are laid within 24 hours after mating. Generally, egg clusters are found on tree trunks, crevices, under loose bark, under or on rocks, tree stumps, foliage, or vehicles. Between 8 and 9 months are spent in the egg. Hairs from the female's abdomen surround the eggs, providing protection from winter temperatures as low as -20°F. Larvae are fully formed inside the eggs about a month after laying, but most lose water content and cease development until spring. Some larvae do hatch in the fall, but do not fully develop. Most larvae complete their development and emerge from the eggs about the time that local trees are producing new leaves.

Most larvae will hatch from an eggmass within a week, but the hatch period may be up to a month from masses in cool, shadowed, or high-altitude areas. Newly hatched larvae are about 3 mm long, and remain near their eggmass if the weather is rainy or if temperatures are below 45°F. Once they have left the eggmasses, larvaes are attracted to light and move upwards, spinning a thread of silk, until they reach the top of whatever object they hatched on. They then rely on the wind to carry them to new locations, using their silk threads as balloons or parachutes. Most larvae migrate even if they hatch on a source of available food.

Larvae feed first on new leaves, during daylight hours. Peak feeding periods occur during early morning and late afternoon hours. When not feeding, the young larvae stay on the undersides of leaves, where they form a silk mat on the leaf surface for attachment.

Molting occurs at intervals of about one week, to allow the larvae to grow and expand. Males usually undergo four molts and females usually undergo five, but up to nine have been recorded.

After the third molt, larvae begin resting in sites other than leaves, and begin feeding at night (with peaks in the late evening and before dawn).

At the end of the larval period, each larva surrounds itself with a sparse silk net, rests for about 2 days, and becomes a pupa. The pupa breaks out of the larval cuticle, turns dark brown, and remains in its silk net for about 14 days if male, or 16-17 days if female. When development is complete, the newly-formed adult breaks out of the pupal skin, expands its wings over a period of several hours, and begins its adult life.

6. Seasonal abundance:

Eggs hatch between mid-April and late May. Larvae are abundant for about 40 days after hatching, until perhaps mid-July at latest. The pupal stage lasts for about two weeks; pupae are generally present until late July at the latest. Adults live 6-10 days, so may be found from early July until late August. Only egg masses are found between the death of one year's adults and the hatch of the following year's larvae.

7. Responses to environmental factors:

A. Weather and Climate:

1. Temperature - Exposure of eggs to temperatures below 32°F for extended periods or to less than -9.4°F for short periods is lethal. Exposure of larvae to freezing temperatures may be lethal. Larval growth is accelerated by exposure to high temperatures (around 90°F).

2. Moisture - Heavy rainfall at hatch may result in drowning of larvae. Rainy weather during the first larval instar can delay migration, and cause larvae to congregate on the undersides of leaves. The duration of this instar may increase under these conditions. Extended congregation may stress larvae enough to make them susceptible to nucleopolyhedrosis virus "wilt" (see Page 14).

3. Light - Gypsy moth larvae are attracted to light just after hatch, leading them to move upward to sites from which they can be moved by wind. Young larvae (instars 1-3) feed during the day, while older larvae alter this behavior, resting during the day and feeding at night. Adult emergence is apparently triggered by daily light/dark cycles as well.

4. Wind - Larvae are dispersed mainly by wind. Newly-hatched larvae trail silk as they climb to treetops or the upper surface of the objects on which they hatched. These larvae are most active during the daytime, when winds are most active. When they encounter wind, they arch their bodies (to catch the wind) and extrude a silk thread which may act as a balloon or parachute. In addition, first instar larvae are covered with comparatively long hairs, which increase their buoyancy in air.

B. Density Of Population - Crowding of larvae can accelerate development. Crowding during the first instar may prolong the dispersal (prefeeding) period, induce additional instars, and result in the production of larger, more prolific adults.

Another change induced by crowding is a phase polymorphism, in which crowded larvae and adults become lighter than normal in color.

Perhaps the most noticeable behavior change induced by larval crowding is the wandering of large larvae during daylight hours.

8. Impact of Gypsy Moth:

8.1 Direct Impact:

The gypsy moth is one of the most effective defoliators of hard and softwood trees. In addition to aesthetic problems and reductions of lumber stands due to repeated defoliation, forests suffering gypsy moth attack may suffer increased risks of fires, due to canopy reduction and accelerated drying of litter. Effects of defoliation on watershed output are unclear at present. In recreation areas, unsightly defoliated areas and wandering larvae can result in decreased visitor use and revenues.

8.2 Indirect Impact: Repeated defoliation of forest trees can lead to increased susceptibility to other pest damage, and alteration of ecologic succession at affected sites (Doane and McManus, 1981).

9. Natural enemies: Many natural enemies of the gypsy moth have been found (Doane and McManus, 1981), including the following:

A. Pathogens:

1. Bacteria - Bacillus thuringiensis; produces a toxic protein during sporulation which, when injested by a larva, causes a lethal disease.

   Streptococcus faecalis; a strain of this organism has been found to kill larvae.

2. Nucleopolyhedrosis virus - This virus causes a "wilt" disease of gypsy moth larvae which ingest it. The dried bodies of infected organisms serve as inoculum for additional infection.

B. Parasites - More than 40 parasitic flies and wasps have been introduced to control the gypsy moth. Among those which have become eatablished are the egg parasites Oocentrus kuvanae and Anastatus disparis, and the larval parasites Apanteles melanoscelus, Brachymeria intermedia, Rogas indiscretus and R. lymantriae. Simons, et al. (1979) list these as well as many native parasites. Native insects do not effectively control the gypsy moth.

C. Predators:

1. Ground Bettles - Four Calasoma species feed on larvae and pupae. C. sycophanta has been successfully released in the southern portions of the gypsy moth range in the U.S.

2. Soldier Bugs - Podisus species.

3. Birds - Cuckoos, orioles, robins, bluejays, crows, chipping sparrows, chicadees, vireos, grackles and catbirds feed on larvae.

4. Mammals - Shrews and white-footed mice eat larvae and pupae, and may be a major factor in maintenance of low gypsy moth populations.

III. GYPSY MOTH MANAGEMENT

1. <u>Population Monitoring:</u>

Several methods are available for monitoring gypsy moth populations. The choice of method should be based on the population level suspected, location of sampling site in relation to the established U.S. infestation area, and resources available. The USDA Forest Service currently provides gypsy moth survey assistance to any Federal agency on request, and should be consulted if you wish to have a survey conducted.

A. Adult Male Trapping - These techniques involved the use of special traps (made of plastic-coated paperboard) with a sticky inner surface, and which are baited with a synthetic form of the sex pheromone produced by receptive female gypsy moths. The trap currently used for gypsy moth surveys by the USDA Forest Service and the Animal and Plant Health Inspection Service (APHIS) is fully described by Schwalbe (1979). Although several variations of the trap design are manufactured, the USDA-approved design is regarded as the most effective, and should be used. A list of current suppliers of USDA-approved traps can be obtained from your regional Forest Service Office, or from the State and Private Forestry Division of the Forest Service, Washington D.C. (203-235-1560).

Pheromone traps should be placed before male moths begin flying (about mid-June). Schwalbe (1979) describes the use of pheromone traps to detect low gypsy moth populations, and to define specific areas of infestation. Pheromone trapping is an effective technique only for relatively low populations, so is recommended for use in areas outside (or on the edges) of established infestations.

The interpretation of pheromone trapping results is subjective; no direct relationships between numbers of trapped males and eggmass counts (see below) have yet been found. Generally, if traps used in a low-density (1 per 3-4 square miles) survey catch large numbers of males (5 or more) in a season, a high-density (16-36 traps/square mile) survey is performed the following season, to identify foci of infestation for possible treatment (Gary Moorehead, personal cummunication).

B. Larval Trapping - The collection of gypsy moth larvae, while not yet useful in quantifying infestations, can serve as another early indicator of a low (e.g., recently established, but building) population. The most convenient method involves tying a 12" wide burlap band around the trunk of each tree to be monitored so that the top 6" of the band can be pulled down over the bottom, making a shaded flap in which larvae will hide during daylight hours. Bands should be monitored two times each week, and any trapped larvae should be destroyed. The presence of gypsy moth larvae in such traps indicates that a population may be developing in the vicinity of the trap site, and that other survey methods should be used to determine whether treatment is required. Tar-paper wrappings and plastic tree flaps have also been used (instead of burlap) for this technique (Noel Schneeburger, personal communication).

C. Eggmass Counting - Several methods have been developed for determining the number of gypsy moth eggmasses in an infested area. Eggmass counts can be done from September through February, allowing more time for interpretation of results, recounts of doubtful results, and selection of treatments than is afforded by the other methods discussed above. The choice of a particular counting method can be made on the basis of availability of resources (e.g., time and personnel) to conduct surveys, and the expected population level. Currentlyused methods include:

1. Threshold walk - An observer walks through the area to be monitored, counting any new (current season) eggmasses he/she sees. The walk ends when the count reaches a predetermined number (see <u>Threshold/action population levels</u>). This method gives no approximation of the actual population level in an area, but it is easily done, and in areas of high gypsy moth population (e.g., established infestation areas) it is useful in making a treat/no-treat decision using accepted threshold values.

2. Five-minute walk - The observer and a companion-guide walk through the area to be monitored for a five-minute period; each counts every detectable new eggmass. The average of the two counts is determined, and converted to an approximate number of eggmasses by the following equation:

$$\boxed{\text{Average number of eggmasses observed} \quad X\ 20} + 15 = \text{Estimated number of Eggmasses per acre}$$

The estimate of eggmasses/acre can be compared to established threshold levels to determine whether treatment is necessary. The equation above was supplied by Noel Schneeberger, of the USDA Forest Service. This technique is most useful in areas of high gypsy moth populations.

3. Fixed-radius plot - The observer counts every new eggmass within a circle of radius 18.6 feet about a chosen point. This count, multiplied by 40, gives the approximate count per acre, which can be compared to known threshold values. This technique is effective where populations are low, and eggmasses may be difficult to find.

4. Fixed-and variable-radius plot counts - This method is described by Wilson and Fontaine (1978). It is more sophisticated than those already described,. provides data which can be statistically compared to data from other areas, and requires significantly more effort than the methods noted above. This method is too time-consuming to be effective for counting high egg mass populations, but is excellent for low populations.

5. Intensive search - Used for very small populations (i.e., no evident defoliation, but with multiple adult male catches in pheromone traps), this method simply involves examination of <u>all</u> surfaces (in the vicinity of traps with trapped males) for eggmasses, including under bark flaps, under rocks, and in tree holes. Intensive searching is recommended to support pheromone trapping for the discovery of new infestations.

In addition to merely providing an estimate of the number of eggmasses in an infested area, these methods can provide the opportunity for the observer to judge the health of the gypsy moth population. Eggmasses which are thick and of large size (about that of a 50 cent piece), showing little or no parasite damage (such as small holes), and containing large quantities of undamaged, fertile eggs indicate a healthy population, which may require treatment. In many cases, a numerically large population producing small eggmasses, and/or showing predator/parasite damage, may be declining, and not require treatment. Of course, any eggmasses found in areas outside the established U.S. infestation area may represent the spread of the gypsy moth, and may require treatment, since isolated infestations may often be eradicated (see Page 16). Within the infested region, management of the moth population to prevent undue defoliation is the best approach, since eradication is impossible.

D. Defoliation monitoring - To date, efforts to determine a numerical relationship between the gypsy moth population level in an area and the amount and severity of defoliation to be expected in that area have been only partly successful at best. Current defoliation thresholds are rough estimates. Therefore, in addition to directly sampling the moth population in a particular area, site managers may wish to indirectly track zones of defoliation to determine:

- Where to treat otherwise-unidentified moth populations;
- Where to set up traps next spring; and
- The progress of existing infestations.

Defoliation is generally monitored (during the period of peak larval development) in the following ways:

1. An observer may make estimates of percentage defoliation of particular trees by walking through the infested area and examining tree crowns through binoculars. A slightly more comprehensive method involves using the Fixed and Variable Radius Plot design noted above (under <u>Eggmass sampling</u>), and again estimating the percentage defoliation noted on each tree observed. Comparing photographs of a sample area taken at regular intervals will allow the observation of changes in canopy density due to defoliation. These methods are very time-consuming, and are subject to errors of interpretation. They are discussed by Talerico (Doane and McManus, 1981).

2. An observer may fly over the area to be monitored in a fixed-wing aircraft, sketching zones of light, medium, or heavy infestation on a U.S. Geological

Survey map of the area. Talerico (in Doane and McManus, 1981) details the procedure and interpretation of such maps. As in ground observation methods, interpretation of the results is largely a matter of experience.

3. Aerial photographs (on false-color infrared film) can be used to accurately identify the locations and severity of defoliation. The U.S. Forest Service presently cooperates with the U.S. EPA and NASA to prepare such photos, and provide training for photo interpretors in gypsymoth-infested states. If you believe that the use of such a system would benefit your gypsy moth control program, contact your NPS Regional IPM Coordinator for further information on Forest Service programs.

2. Threshold/action population levels:

The following population values are currently used by the USDA Forest Service and APHIS in their gypsy moth management programs. It should be noted that the goal of the Forest Service program is to maintain moth populations below levels producing significant defoliation, while that of the APHIS program is the eradication of isolated gypsy moth outbreaks.

A. For areas in established infestation zones:

200-250 eggmasses/acre; moth population will produce noticeable defoliation. Treatment is recommended for high-use recreational areas (campgrounds, trailer parks, other areas with transient traffic).

B. For areas outside established infestations:

5 or more male adults per delta trap (USDA pheromone trap), count obtained using low-density trapping (1 trap per 3-4 square miles); triggers follow-up high-density trapping (using a regular grid of 16-36 traps/square mile; the trap density should be greater in high-value areas), intensive searches for eggmasses, and eradication treatments where infestations are located by these methods.

3. *Management alternatives - nonchemical:*

A. *Bacillus thuringiensis* - This spore-forming bacterium produces a crystalline protein (during sporulation) which is toxic to the larve of many species of butterflies and moths, including the gypsy moth. Predators and parasites of the gypsy moth are not harmed by the toxin, nor are humans, plants, or other animals. A complete review of the properties and action of *B.t.* toxin can be found in Doane and McManus (1981). *B.t.* is an effective alternative to chemical pesticides used against *L. dispar*, and is currently available in a number of commercial products, including Dipel (Abbot Laboratories); Bactospeine, Leptox, and Novabac-3(Biochem Products); Certan and Thuricide (Sandoz), SOK-Bt (TUCO), and Gypsy Moth Caterpillar Control (Reuter). Label directions should be followed at all times.

B. *Nucleopolyhedrosis virus (NPV)* - This virus is the cause of an endemic "wilt" disease of gypsy moth larvae in the U.S. and Europe. A review of the natural occurence (gypsy moth NPV is a major cause of naturally-occuring moth population declines), culture, and testing of NPV as an artificially-applied larvacide is included in Doane and McManus (1981). Currently, NPV is not used in gypsy moth control programs due to ineffectiveness and the lack of an easily-applied formulation (Noel Schneeberger, personal communication).

C. *Other predators and parasites* - While many naturally-occuring predators and parasites are known, none has been sufficiently well studied to permit commercial development or large-scale release. The best way for a site manager to make use of available predators and parasites is to use management alternatives (e.g., *B.t.* or no treatment) which will not adversely affect them, so that they can function as a part of the gypsy moth IPM program. See Doane and McManus (1981) for a detailed discussion of predator/parasite research. Eggmass surveys and larval surveys can include observations of predator/parasite presence as a guide to maximizing their effectiveness. Contact your regional Forest Service office for assistance in conducting such surveys in your area.

D. *Genetic control* - The release of sterilized male moths has been attempted as a means of control. Females which mate with sterile males should not produce offspring, since females usually mate only once. This method is expensive, and is probably only effective in controlling small, isolated pockets of infestation. See Doane and McManus (1981) for a detailed discussion of the USDA sterilemale release research program.

E. Favored-host removal - Since the demise of the American chestnut as the dominant overstory tree in Eastern U.S. deciduous forests, oaks have become the dominant species. Unfortunately, oaks are also the favored hosts of the gypsy moth throughout its range. In the absence of external control measures, repeated defoliation of favored trees may result in a shift of dominance to nonhosts and lessfavored hosts, such as maples. This will, ultimately, reduce the magnitude of the gypsy moth problem in these areas. While selective removal of favored gypsy moth hosts is an impractical (at best) solution for most park sites, selection of planting material for areas under development (e.g., urban parks) to exclude favored hosts is certainly feasible. See Section II.4 for a list of less favored and nonhost trees.

F. Regulatory control - APHIS has designated a large area of New England, the Middle Atlantic States, and portions of Michigan as "gypsy moth high risk areas" (Anonymous, 1983). Individuals moving household or recreational items from these areas into or through other areas of the U.S. must have such items inspected and certified gypsy-moth-free by a USDA-trained inspector. Since gypsy moth larvae may hide on (and females frequently deposit their eggmasses on) exposed surfaces of vehicles, camping equipment, and other items, inspection of the vehicles and equipment belonging to park visitors from high-risk areas may enable park personnel to discover and destroy eggmasses and other gypsy moth life stages which could give rise to new infestations. Distribution of educational materials (e.g., Anon., 1983) to prospective visitors to all parks outside the "highrisk" areas, along with the erection of prominent informational displays outside park boundaries are recommended as methods to encourage visitors to voluntarily participate in such a program. Contact your regional NPS IPM Coordinator or local APHIS office for aid in setting up such a program.

The establishment of a pheromone-trapping program in areas of high vehicular traffic and other visitor use is recommended as an adjunct to any inspection program, to permit the discovery of isolated infestations caused by eggmasses or other life stages slipping through the inspection program. Contact your local Forest Service office for details and assistance in conducting a trapping program.

4. Management alternatives - chemical:

A. Gypsy moth pheromone - The sex pheromone produced by female gypsy moths to attract males (cis-7,8-epoxy-2-methyloctadecane, or 'disparlure') has been synthesized. While disparlure is widely used to monitor adult male population levels (see Section III.1.), it has also been used to control small populations (e.g., isolated outbreaks along the "leading edge" of the infestation) by trapping males in pheromone-baited sticky traps, and by disrupting mating behavior. Currently, USDA-APHIS uses pheromone traps (at 3/acre, or 2,000/square mile) in conjunction with double applications of *Bacillus thuringiensis* in attempts to eradicate small outbreaks in selected areas of the U.S. (Gary Morehead, personal communication). If you suspect such an outbreak in your area, consult your local Forest Service representative for information and assistance in evaluating the feasibility of and/or setting up an eradication program.

B. Chemical insecticides - Insecticides currently registered for gypsy moth control include dimilin, carbaryl, acephate, and trichlorfon. NPS policy states that these pesticides may only be used in (historic or developed) park areas in which *B.t.* or other biological methods (or pheromone trapping) are ineffective. Contact your regional NPS IPM Coordinator for further information.

5. Summary of Management Recommendations:

The USDA Forest Service is responsible for conducting gypsy moth population monitoring programs in all Federal lands. Each park manager should contact his/her regional USDA-FS office for assistance in setting up an appropriate gypsy moth monitoring program for high-use areas. For further information regarding USDA-FS services, contact the:

Director, Forest Pest Management
State and Private Forestry Division
USDA Forest Service
FTS: 235-1560 (commercial area code 703)

In historic and developed areas (including campgrounds, visitor facilities where shade is an important attraction, and specimen trees), survey programs may trigger treatments with Bt for suppression or eradication. Under NPS policy, natural areas may receive no treatments; existing natural enemies must be allowed to exert their long-term effects in such areas.

IV. BIBLIOGRAPHY

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NATIONAL PARK SERVICE
IPM Information Package

MOSQUITOES

Final Report

27 July 1984

Submitted To:

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U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

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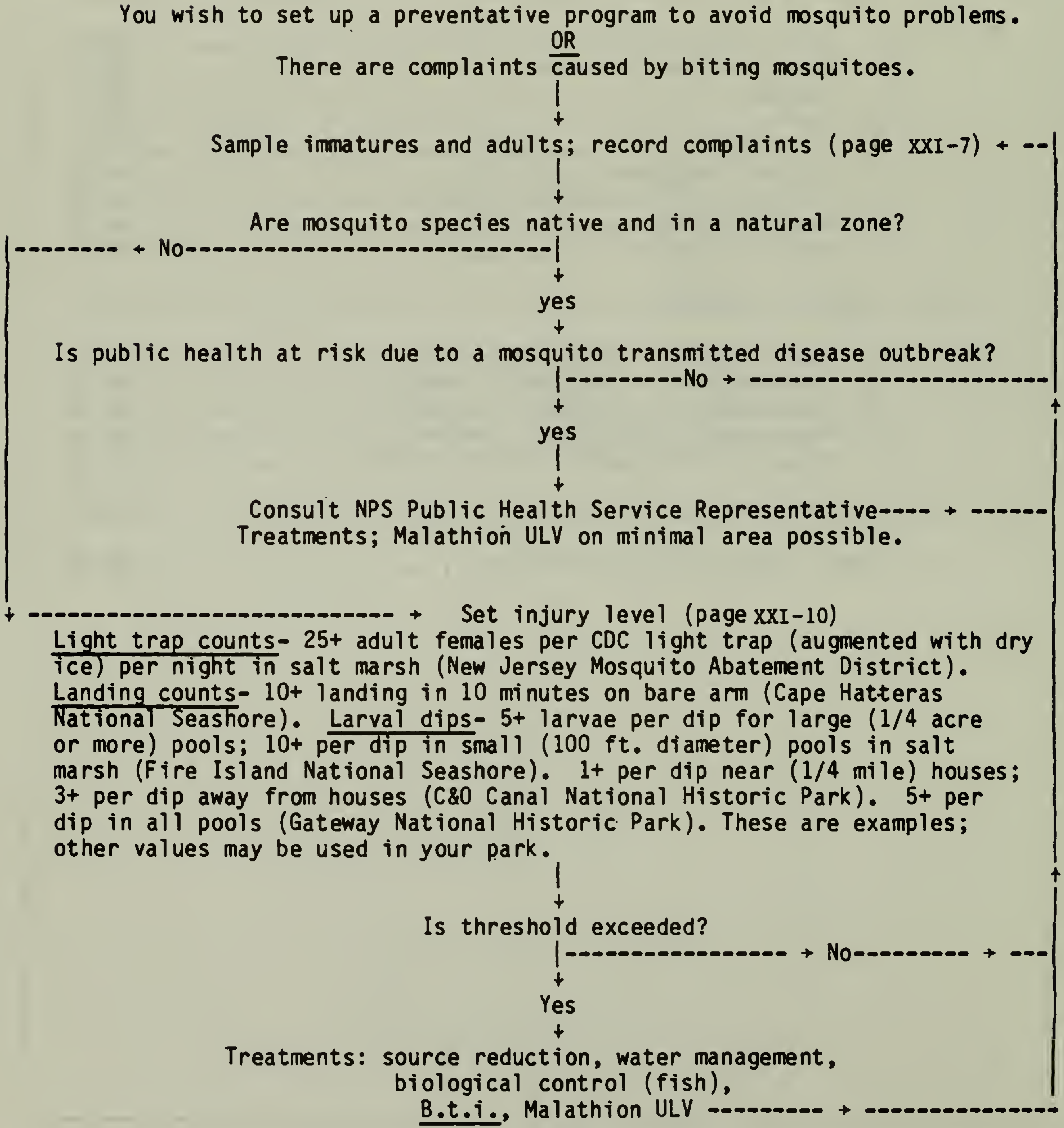
CONTENTS

I. MOSQUITO IPM DECISION TREE

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



You wish to set up a preventative program to avoid mosquito problems.

OR

There are complaints caused by biting mosquitoes.

Sample immatures and adults; record complaints (page XXI-7)

Are mosquito species native and in a natural zone?

No

yes

Is public health at risk due to a mosquito transmitted disease outbreak?

No

yes

Consult NPS Public Health Service Representative

Treatments; Malathion ULV on minimal area possible.

Set injury level (page XXI-10)

Light trap counts- 25+ adult females per CDC light trap (augmented with dry ice) per night in salt marsh (New Jersey Mosquito Abatement District). Landing counts- 10+ landing in 10 minutes on bare arm (Cape Hatteras National Seashore). Larval dips- 5+ larvae per dip for large (1/4 acre or more) pools; 10+ per dip in small (100 ft. diameter) pools in salt marsh (Fire Island National Seashore). 1+ per dip near (1/4 mile) houses; 3+ per dip away from houses (C&O Canal National Historic Park). 5+ per dip in all pools (Gateway National Historic Park). These are examples; other values may be used in your park.

Is threshold exceeded?

No

Yes

Treatments: source reduction, water management, biological control (fish), B.t.i., Malathion ULV

II. MOSQUITO BIOLOGY AND ECOLOGY

1. Species Described: Major pest genera (other genera may be of local importance):

   A. Aedes

   B. Anopheles

   C. Culex

   See pages 134-166 of U.S. Department of Health, Education, and Welfare (1967) for a comparative key to common mosquitoes. Also see Darsie & Ward, (1981) for detailed keys to larvae and adult females of all species found in North America.

2. Geographic Distribution: Mosquitoes are found throughout the world on every continent except Antarctica. They occur wherever liquid water exists for breeding.

   See Hackett & Giraldi (1982), Carpenter (1955), Pratt (1959), or Green (1982), for detailed information.

3. Habitat:

   A. Aedes - Species in this genus generally breed in temporary or isolated pools of water such as woodland pools, flood pools, pools in salt marshes, rock pools, tree holes, etc.

   B. Anopheles - Species in this genus generally breed in permanent water such as ponds, wells, seeps.

   C. Culex - In general, species in this genus breed in permanent water. Culex mosquitoes often breed in polluted water and are fairly common around towns and in homes.

4. Hosts: Female mosquitoes bite to obtain blood for egg development. Different species attack different hosts (e.g., humans or other mammals, birds, reptiles, amphibians). Some species only attack one host group while others are more general feeders. Females find hosts primarily by detecting the carbon dioxide (CO_2) exhaled by the host.

5. **Life Cycle:**

A. Aedes - Aedes mosquitoes usually overwinter in the egg stage some species overwinter as larvae, pupae, or as hibernating adults). Eggs may hatch (depending on the species) as soon as ice melts in woodland pools (*Ae. canadensis*) to throughout the season. Most *Aedes* mosquitoes produce one generation per year. Some species may have several generations depending upon water temperature, and the number of floodings or amount of rainfall. Again, depending on the species and water temperature, growth from egg to adult takes from 4 days to a month. *Aedes* species normally oviposit above the water line. Eggs hatch when flooded. Some species (floodwater and saltmarsh mosquitoes) lay eggs up to several feet above the mean water level; spring floods or high tides inundate the eggs, causing them to hatch.

Larvae (wrigglers) are found only in water. They breathe air at the surface. Larvae pass through 4 stages or instars before they pupate. Larvae feed on microorganisms by means of fan-like hairs which sweep water to the mouthparts.

Pupae (tumblers) are found only in water. Like larvae, they breathe at the surface, but pupae do not feed. The pupal stage is essentially a time when the mosquito rebuilds itself to form a winged, non-aquatic, sexually mature adult stage from the larval tissues.

Adults are the flying reproductive stage. Females are biters; they can fly from 1 to 25 miles for a blood meal, depending on the species (blood is used for egg development). They also drink nectar from flowers for flight fuel. Males do not bite; they sip nectar from flowers. Males emerge as adults before females (this may be useful in monitoring programs). Some species can produce eggs without a blood meal.

B. *Anopheles* - *Anopheles* mosquitoes have life cycles similar to those of *Aedes* species with several important exceptions:

Anopheles mosquitoes ususually overwinter as hibernating adults (some species overwinter as larvae or in the egg stage).

Most *Anopheles* mosquitoes lay single eggs on the surface of calm water in wind sheltered locations. Choppy water or running waters are not suitable for mosquitoes because waves may strike ovipositing females causing them to be trapped by surface tension, or turbulence may drown larvae. These areas also generally contain fish which feed on mosquito larvae.

C. *Culex* - *Culex* mosquitoes have life cycles similar to those of *Anopheles* species. They differ in that most species of *Culex* lay their eggs in multiple "rafts" which float on the surface of the water.

6. **Seasonal Abundance:**

Mosquitoes may breed and develop any time from the beginning of spring to the first hard frost of fall. In general, populations are highest in summer and early fall. Under ideal conditions, many species can complete development in less than a week resulting in large populations of flying adults.

7. **Effects of Environmental Factors:**

Mosquito populations are influenced by temperature and rainfall. Prolonged or abundant rains can cause more eggs to hatch by raising water levels; large numbers of adults can breed in the larger, more permanent pools. Temperature has less effect on large pools due to the thermal buffering capacity of water. Conversely, lack of water and low temperatures result in lower populations.

8. **Medical Importance:**

8.1. Direct Effects:

Although mosquitoes have been reported to cause death from excessive blood loss in livestock (presumably a helpless human could suffer a similar fate), the direct effect of mosquitoes and mosquito bites is usually annoyance.

8.2 Indirect Effects:

With the decline in frequency of malaria and yellow fever, encephalitis has become the most important mosquito-vectored disease in the U.S. Encephalitis is a viral disease which attacks the central nervous system. Five types of arboviral (arthropod-borne viral) encephalitis occur in the U.S. They are eastern equine encephalitis (EEE), western equine encephalitis (WEE), California encephalitis (CE), St. Louis encephalitis (SLE), and Venezuelan equine encephalitis (VEE). Each type is caused by a different virus or virus complex, and each has a different disease cycle. CE and VEE are transfered by mosquitoes among small mammals and then to man or horses (in VEE) often by the same mosquito species. EEE, WEE, and SLE are transmitted from bird to bird by one mosquito species and from bird to man or horse by another mosquito species.

Dog heartworm is a mosquito transmitted nematode parasite of dogs and occasionally of man. It occurs throughout the U.S. and is common in the East. Untreated, it can be fatal to dogs. The precise vectors of dog heartworm in the U.S. are not entirely known but many species of mosquitoes have been infected under laboratory conditions. Use of medication to protect dogs from heartworm is generally a more effective means of controlling this disease than is mosquito management.

9. **Natural Enemies:** Mosquitoes have many natural enemies, ranging from bacteria and insects to fish and birds. Natural enemies attack all stages of the life cycle from egg to adult. Many natural enemies can be and are used to provide biological control.

III. MOSQUITO MANAGEMENT

1. Population Monitoring Techniques:

Monitoring consists of site visits to potential mosquito problem areas, and sampling and interpretation of data. Data to be sampled include: complaints of bites to determine the degree of nuisance (injury level); numbers of mosquito immatures and adults (to determine which species are present and their numbers) and people usage patterns (as related to creation of mosquito breeding sites and as related to contact between mosquitoes and people). Keeping records of observations and samples, including the use of site maps, is essential. Local mosquito abatement officers should be consulted before monitoring begins.

A. Aedes The initial site visit should be made before mosquitoes have hatched in the late winter/ early spring. This will allow time to identify all potential mosquito breeding sites and biting areas, and implement changes to avoid mosquito problems (habitat modifications, purchase of control agents, etc.).

1. Monitoring larvae and pupae - Mosquito larvae and pupae are monitored by a 10-dip method using a standard dipper made of enameled metal or aluminium. See Hackett and Giraldi (1982), for details. Dippers can be purchased through biological supply houses or hardware stores. Counts are recorded and averaged for each pool.

Take 5 samples from open water and 5 samples from the pool edge, particularly an edge with vegetation. If possible, intermingle samples from sunny and shady areas as well. Try to be consistent in sampling technique. See Hackett and Giraldi (1982) for further details.

Since larvae and pupae will dive to the bottom of the pool if disturbed, the recommended method of sampling is as follows: (a) to sample in open water, gently cut the surface of the water with the dipper edge and allow immatures to be drawn in; (b) to sample along banks or in dense vegetation, press the dipper into the side of the bank or against dense vegetation, and (as above) draw immatures into the dipper. Try not to cast a shadow on the area you are sampling. If larvae become disturbed, either wait until they reappear, or sample different areas within the same pool. Mosquito larvae not accesible with a dipper (i.e., in tree holes, tires, etc.) should be sampled with a large basting syringe and emptied into a white pan for counting. (Basting syringes can be obtained in housewares stores; white pans or developing trays are available in photography shops).

Sample all selected indicator pools (representative of all pools in the park area where you are considerin control). Establish a sampling circuit and sample all selected pools on a regular basis, usually weekly (spring and fall) or daily to weekly basis (summer). If no permanent habitat changes are made, sampling should continue until the first hard frost of autumn.

To make sure that the immatures you are controlling are the same mosquitoes that are the problem, comparisons of larval and adult specimens sampled are necessary. Use available literature and CDC Keys to identify specimens. Unless you can identify both adult and immature specimens to the species level, it is better (at least in the beginning) to send specimens out for identification. Contact local universities, colleges, or other institutions for such services.

2. Monitoring adults - To monitor adults, sample all nuisance or disease transmitting species in your area (see your local mosquito abatement district officer for a list). Establish a sampling circuit and sample on a regular daily or weekly basis. Begin sampling as soon as larvae pupate and continue until the first hard frost of autumn. Landing counts (See 2.b.) are extremely useful during the day. However light trap counts must be made at night. Sample all areas where mosquitoes may be a nuisance due to their biting, particularly park areas adjacent to residential areas. Check with the local mosquito abatement officer for proper placement of traps.

a. Light traps

Light traps catch large numbers of mosquitoes, and are simple and inexpensive over the long run. They are <u>not</u> a control measure, but are a monitoring tool only. Different traps catch different mosquito species; therefore, it is important to use a trap that will survey all problem mosquitoes in the area. Consult your local mosquito abatement district officer

New Jersey or CDC Mini traps are the most commonly used. Since mosquitoes are primarily attracted to carbon dioxide in the host's breath, light traps are often augmented with dry ice. A 1 lb. (or larger) block of dry ice is wrapped in newspaper or foil, and hung next to the trap. CO_2 supplements increase the mean catch up to 100 times of that in light traps without CO_2. It also allows traps to be used on moonlit nights or around street lights which normally "compete" with the light from most traps. Use of dry ice allows traps to be used in daylight to sample day flying species as well as species not attracted to light (such as many Anopheles).

Downing (1979) provides detailed instructions for interpreting mosquito trap data. If the use of this procedure is not possible, determine average catch from all traps set in an area. Consider using the services of local mosquito abatement district offices in analyzing the data.

b. Landing counts

Landing counts on humans are useful in that they provide an accurate monitoring method of the species that are biting human beings. In order for this index to be useful, counts must be made during mosquito feeding periods. Since many mosquitoes feed during the day, landing counts are often a valuable monitoring tool to use during daylight hours. They can also be used at night from 30 minutes before sunset to 30-45 minutes after sunset to sample crepuscular biters (those active before and after dawn or dusk).

The person conducting the landing count survey walks into the survey area to disturb the mosquitoes. After waiting about a minute, he counts(and if possible, collects with an aspirator) the mosquitoes landing on arms or legs. Counts on clothing below the waist result in better data with less discomfort. Depending on mosquito abundance, time intervals of 1, 5, or 10 minutes may be used.

Regardless of the method or time interval used, the same procedure should always be followed so that comparisons between counts can be made. The same person should always be the "bait" because mosquitoes are attracted differently to different people.

As with other monitoring measures, little data exist on the relationship between landing counts and injury levels. This might be determined by correlating landing counts with citizen complaints. This technique is especially useful early in a monitoring program, before long-term trapping data are collected. The landing count survey samples that portion of the female mosquito populatio which is seeking human blood.

c. Evaluation of treatment success-

The easiest way to evaluate treatments is to compare indicators of mosquito nuisance before and after treat ment. Since the ultimate goal is to reduce mosquito biting to a tolerable level, changes in indicators whi measure this (complaints or annoyance determined by surveys) are the best criteria for evaluation of the entire program. In many cases, the effectiveness of specific treatments can be evaluated by monitoring changes in the sizes of populations of immatures or adults.

A simple evaluation method (one which does not requir complicated statistical analyses) is to plot complaint versus counts of immatures or adults on graph paper. Complaints should correlate with counts of mosquito adults in light traps and immatures in pools.

B. *Anopheles* - See Section III.1.A. (*Aedes*).

C. *Culex* - See Section III.1.A. (*Aedes*).

2. Threshold/ Action Population Level:

Injury levels will vary from park to park. They should correlate with complaints, adult trap monitoring, and larval monitoring. Record the number and location of complaints, decide what you consider to be an unacceptible number of complaints: this is the injury level. Establish an action threshold. Determine how many mosquitoes are flying as indexed by trap counts and landing counts to cause the number of complaints to reach the injury level. Determine how many mosquitoes will emerge if larvae are untreated. The action threshold is the number of flying adults and untreated larvae which will, after emerging, push the average trap catch to one mosquito per trap per night below the injury level.

Working injury levels/action thresholds have been set in several units of NPS. Larval samples of 1 to 5 per dip, adult trap counts of 25+ adult females per night, and landing rates of 10+ in 10 minutes have been used in IPM programs with success.

3. Management Alternatives - Nonchemical:

A. *Aedes*

1. Water management - Since all mosquitoes are aquatic i the immature stages, good water management is the preferred treatment. In comparison to adults, larvae are more concentrated and easier to deal with. Any

mosquito abatement program should have larval control, particularly water management, as its first priority.

Water management may provide control for as long as 10 years without maintenance costs and may pay for itself (in terms of money saved in yearly pest control) in some situations within 4 years (Shisler, 1981). Caution should be taken in natural areas so that natural drainage patterns are not changed.

Water management may be as simple as removing breeding sites such as discarded cans or old tires in which several species (e.g., Aedes aegypti; the yellow fever mosquito) breed.

Drainage - Many ground pools and other breeding sources may be eliminated by connecting them via graded ditches to larger and deeper bodies of water such as rivers or lakes. Ditching serves two purposes: in some cases the water drains out of the potential breeding sites, in others, fish gain access to isolated pools and prey upon the larvae there (this is usually the case in salt marshes). Ditches can be constructed using hand tools or machinery especially designed for this purpose.

Filling - Many ground pools that are not easily drained may be eliminated by filling them with earth, using hand tools or machinery.

Ponding - Ponding essentially means turning a temporary pool into a permanent one. In some cases, the water level may be raised to the point where it can support mosquito-eating fish which are then stocked. Variations on ponding include the construction of sumpage wells, where the water is drained into a relatively deep pool and stocked with predators or other natural enemies. In salt marshes, pools may be dug to serve as refuges for fish during low tides. When high tides flood the marsh, fish are then able to forage widely. Water impoundment (stop ditching) in salt marshes is another variation of ponding. This technique is used in areas in which large numbers of breeding pools occur over an extensive area. A large body of standing water 6-12 inches in depth is created in these areas by use of low level dikes. For example, impoundments have been built to interrupt tidal flows and allow water from upland areas to flood salt marshes. These impoundments, although controlling salt marsh mosquitoes, may create breeding area for other pest species. The area of impounded water should, therefore be monitored if this technique is used.

In some areas this method has resulted in geobiochemical problems (e.g. increased vegetative succession, decreased diversity, and increased number of other species of mosquitoes).

2. Biological control -

a. Fish - Mosquito eating fish have long been used for mosquito control in many areas of the world. The most commonly used species is the mosquito fish, Gambusia affinis, but many other fish species have been used with varying degrees of success. Fish are particularly useful mosquito control agents in the following habitats:

Deep permanent pools - Due to their temperature buffering capacity, these provide the best conditions for fish survival. Permanent pools support algae, which are desirable food for young fish and may serve to prevent cannibalism by adult fish. Before using fish in permanent pools, check to see if fish are already present and are controlling mosquitoes. Determine the thickness of ice in winter. If ice becomes too thick, fish must be restocked in spring.

Large areas of temporary water - Use of fish in temporary pools may be useful where fish are easily obtained and where use of water management or other methods would be prohibitively expensive. This procedure was used on an experimental basis in the high salt marsh area of Fire Island National Seashore; fish in this case were collected from the lower marsh.

Highly polluted water - Fish may be useful in areas which are too polluted (high in organic material) for other methods to work. Fish have been used to control mosquitoes in primary sewage treatment ponds and tanks.

Before using fish for biological control, several factors must be considered: in ornamental ponds, goldfish will eat mosquito larvae but are not considered to be particularly useful in mosquito control. Water temperature must be above 50°F for guppies to survive.

Both mosquito fish and guppies can tolerate low dissolved oxygen levels and high levels of pollution. Mosquito fish are able to gulp surface air in low oxygen environments. Guppies can survive and reproduce in sewage treatment facilities and tolerate high metal ion concentrations. Mosquito fish have been used in sewage treatment plants but must be gradually acclimated first. Both fish species can tolerate a wide range of pH and salinity.

Neither mosquito fish nor guppies do well if predatory fish (such as bass or sunfish) occur in the same waters unless there is very shallow water for a refuge. Guppies are outcompeted by mosquito fish and soon disappear from areas where the two occur together. Birds such as herons and kingfishers may be problems in small bodies of water with limited populations of fish.

Fish exotic to an area should not be introduced into waters where they may compete with native (endemic) species. In Texas, the Big Bend Gambusia (*Gambusia gagei*) was nearly eliminated when the mosquito fish (*G. affinis*) was introduced into its only known habitat, a pond near the Rio Grande. Other rare or endangered fish occur in scattered areas throughout the U.S., particularly in the Southwest. Consult with park and regional resource management personnel before making any introductions.

Fish effectiveness is decreased in the presence of floating vegetation which provides cover for mosquito larvae. Overhanging walnut or mulberry trees may lower effectiveness due to toxins released by leaves which fall into the water.

For more detailed information on mosquito control using fish, see Hackett and Giraldi (1982) and Coykendall (1980).

b. Predaceous insects - Insects, especially backswimmers (notonectids), may, when present in significant numbers, stabilize mosquito larvae populations. Although predaceous insects may be slow in reducing high larval numbers, when used in conjunction with other control measures (fish, *B.t.i.*), they can keep larval populations below the action threshold. The ratio of backswimmers to mosquito larvae per dip may provide an action threshold for determining whether additonal control measures are necessary.

c. Parasitic nematodes (roundworms) - *Romanomeris culicivorax* kills mosquito larvae by penetrating the body and feeding on internal tissues. The larva eventually ruptures, releasing more nematodes. Successfully tested in the field throughout the world, it is persistent in breeding pools and survives at least two years after initial introductions. It can be obtained by special order from:

The Nematode Farm
2617 San Pablo Ave.
Berkely, CA 94702
ATTN: Andy Wilson
(415)527-8260

B R Supply Company
P.O. Box 845
Exeter, CA 93221
(209) 732-2738

d. Bacteria- The bacterium Bacillus sphaericus has been used experimentally to suppress larval populations. Similar to B.t.i., it can be used in polluted water where B.t.i. is less effective.

Bacillus thuringiensis israelensis (B.t.i.) is quickly becoming one of the most important mosquito control tools worldwide. It is highly selective for mosquito and black fly larvae. It is nonhazardous to human beings, other mammals, birds and predaceous insects, is reasonably priced and easy to ship and store, easy to apply, and fast acting.

e. Fungi- The parasitic fungus Lagenideum giganteum acts in much the same way as do nematodes, infecting the mosquito larva's body and growing on tissues, eventually reproducing and infecting other larvae. Recently mass produced, it should be available commercially soon. For further information, contact: J. Kerwon or R. Washino, Department of Entomology, University of California, Davis, Cal. Other fungi are under study; as yet, none are registered for use against mosquitoes.

3. Screens and repellents may reduce mosquito annoyance. Screens over windows and doors will keep many mosquitoes from entering structures. An 18x18 mesh size works best. Protective clothing includes long trousers long sleeved shirts, gloves, and in some areas, hats and veils. Many repellents, varying in effectiveness and duration are currently commercially available.

B. Anopheles - See III.3.A (Aedes).

C. Culex - See III.3.A. (Aedes).

4. Management Alternatives - Chemical:

Although water management is the preferred way to control mosquitoes, chemical controls may sometimes be necessary. Consult your regional IPM Coordinator to determine which pesticide, if any, is best suited to your mosquito management program.

A. Aedes

1. Larvicides - In situations where B.t.i. is not useful (in highly polluted or alkaline water), the following chemicals are registered for larval control: chlorpyrifos, fenthion, pyrethrin, and temephos. Check the labels for rates and formulations. Fish are highly sensitive to most larvicides. Oils are often used in control of immatures. They act by clogging the breathing tubes of larvae and pupae causing suffocation. Oils commonly used are kerosene, diesel #2, fuel oil #2, ARCO larvicide, and Flit MLO®. All but the last may be toxic to fish.

   Insect growth regulators (IGRs) such as methoprene do not kill larvae, but prevent them from developing into adults. Timed-release briquets are available and have been used in a variety of situations. Some IGRs (such as Dimilin which inhibits chitin formation) may have adverse effects on nontarget species, but most are considered harmless to most non target species. They are normally used in small volumes of water. They have no effect on pupae or 4th instar larvae.

2. Adulticides - When adulticides are needed, it usually means something has gone wrong with the IPM program. An IPM program directed at immatures normally obviates the need for adulticide use. However, in certain circumstances, adulticide use may be necessary.

   Most adulticide applications are ultra-low volume (ULV) applications, in which undiluted pesticide is broken into microscopic droplets. A small amount of pesticide is used (2-4 oz/acre). Malathion, pyrethrins, resmethrin, naled, chlorpyrifos, and fenthion are used in ULV applications. ULV applications are quickly dispersed and temporary, killing only insects which are contacted by droplets. Mist blowers may be used to spray dilute pesticides onto surrounding areas to kill resting mosquitoes. Malathion, naled, pyrethrins, and resmethrin can be used in this method. Fogging is rarely used due to expense, lack of coverage, lack of persistence, and its negative effect on air quality.

B. Anopheles - See III.4.A. (Aedes).

C. Culex - See III.4.A. (Aedes).

5. Summary of Management Recommendations:

1. If possible, begin water management program to reduce suitable breeding habitat.
2. Use biological control agents such as fish, nematodes or predaceous insects to reduce larval populations. Use *B.t.i.* instead of chemical larvacides.
3. If use of *B.t.i.* is not possible, treat larval populations with approved pesticide.
4. Treat adults if necessary with approved pesticide such as malathion ULV.

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IV. Sample Mosquito Monitoring Form

Site Monitoring Form

Map

Date:
Reference #:
Samplers:
Location, Distance, and Name of Nearest Town (or major landmark):

Land Use:

Adults

Landing counts
- time of count:
- number & species:

Trap catches:
- type of trap:
- time of trapping:
- # and species:

Collections: Y N
Photos: Y N
Treatment:
- Material:
- Rate:
- Area Treated:
- Equipment:

Immatures

Pool type:
Pool bottom:
Pool depth (in.):
Water conditions:
stagnant, moderate, fast
clear, turbid, polluted

Mosquito collections: Y N
Species present:

Photos: Y N
Predators:

Treatment:
- Material:
- Rate:
- Area Treated:
- Equipment:

Other Recommendations/Comments

Instructions for use - Notes on filling out the site visit form

- Always assume someone else will be the next to visit the site; be as clear as possible. Use pencil-ink will run if wet.

- Habitat information (pool type, pool bottom,etc.) can be used in predicting where and when to expect mosquitoes to be a problem in the park. This is because mosquitoes are not found in every pool of water. Correlations between mosquito presence and habitat type might allow you to anticipate problems.

- Pool type: pond, lake edge, woodland pool, swamp, marshy depression, stream margin, rock pool, seepage spring, flood pool, ditch, pit, well, artificial container (specify), tree hole, wheel rut, other (identify).

- Pool bottom: mud, sand, gravel, rock, leaves

- Pool depth: in inches

- Water conditions: circle one in each group

- Sketch a map of the area on the upper half of the form. Draw outlines of all pools. Include landmarks, direction of nearest town, etc.

- Take a 10 dip sample and record data beside sample pool on map. Use an "S" to mark the area of the pool sampled.

- For adult sampling, specify the type of adult monitoring used (ie. CDC light trap, landing counts, etc.) The map is large scale, when adult monitoring is done in areas removed from the breeding pools. This provides a better picture of the area being monitored and the relationship to human activity.

NATIONAL PARK SERVICE
IPM Information Package

HOUSE MOUSE

Final Report

February 1984

Submitted To:

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

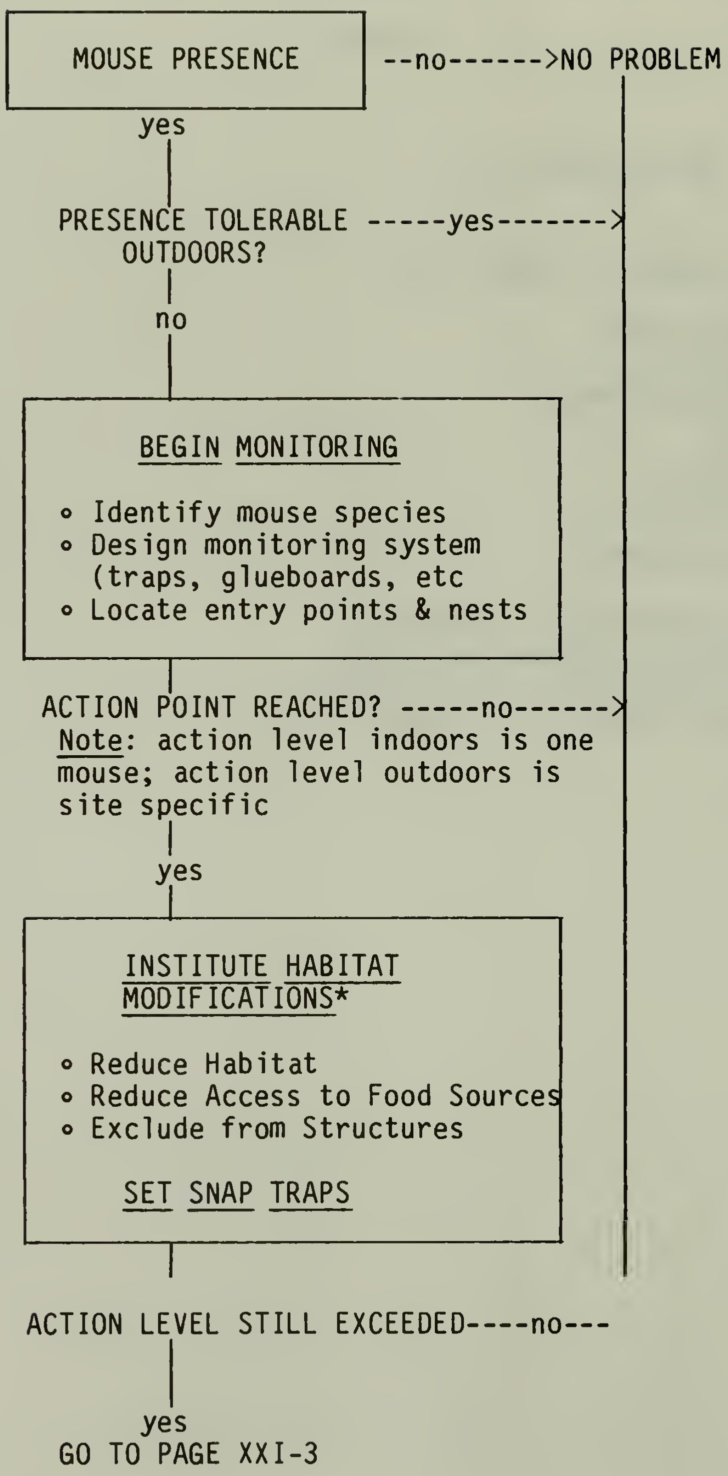
Submitted By:

John Muir Institute
743 Wilson Street
Napa, California 20852

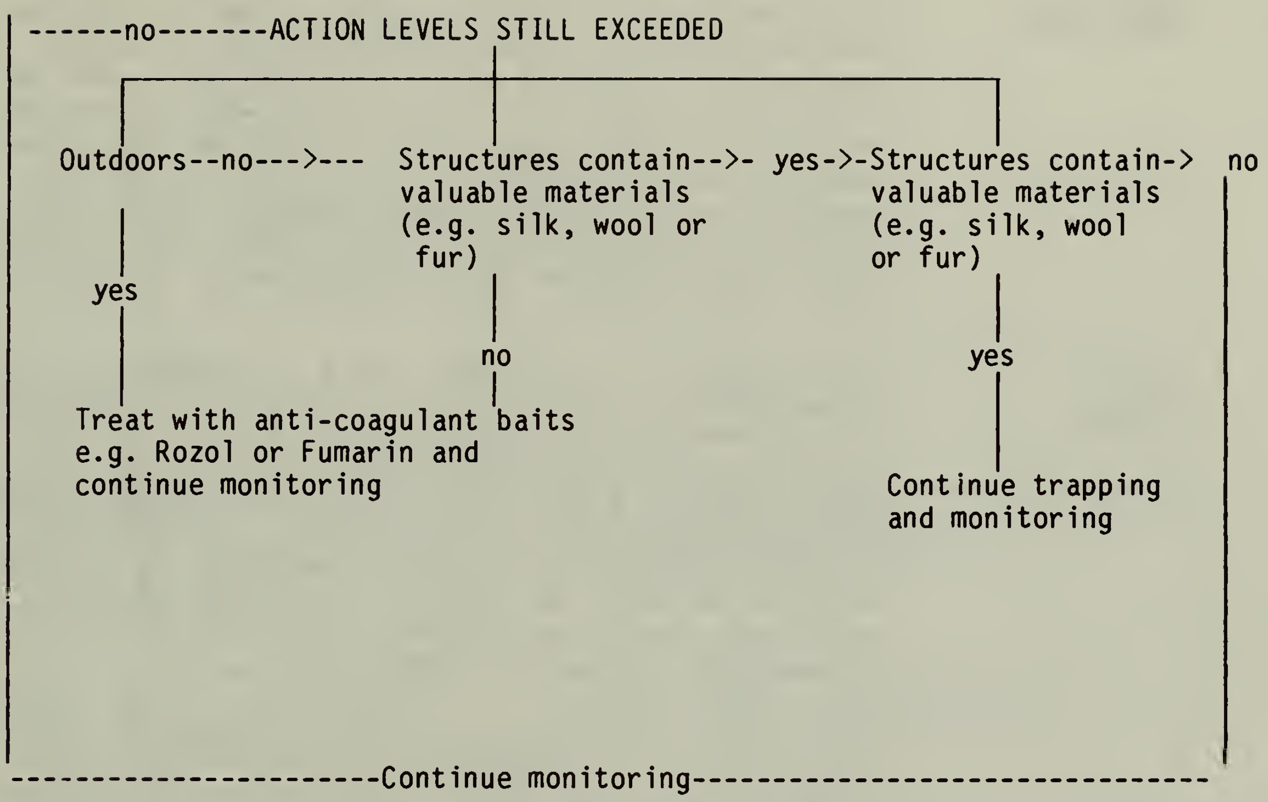
NATIONAL PARK SERVICE IPM INFORMATION PACKAGE

CONTENTS

I HOUSE MOUSE IPM DECISION TREE



I HOUSE MOUSE IPM DECISION TREE CONTINUED



* Outdoor habitat modifications can include reducing vegetation and physical objects which provide hiding places and protected runways close to structures. Indoors, destroy nests and exclude mice from stored foods, wastes and nest-making materials by placing these in closed metal or glass containers.

II BIOLOGY AND ECOLOGY OF HOUSE MOUSE

1. Species Described: The first step in assessing the pest problem is to identify correctly the invading species. Table 1 lists the characteristics of native mice species which could be confused with the house mouse, *Mus musculus* L., and the young roof or sewer rat, both of which were accidentally imported into North America from the Old World. Table 2 compares the house mouse with the Norway rat and the roof rat. A field key for common rodents, including *M. musculus*, is presented by Pratt and Brown (1976). Also, see the Pictorial Keys issued by the Center for Disease Control (CDC 1967).

2. Life History: The reproductive rate of house mice is formidable. Mice become sexually mature when 2-3 months old. The females are polyestrus, having periods every 4 days. Mating takes place over the entire estrus period and at other times as well. A post-partum estrus with delayed implantation during lactation also can occur. Assuming an average litter size of 6.7, and a gestation period of 20 days plus an eight day period during lactation when estrus does not occur, one pair of mice theoretically can produce 87 young per year (see Table 3).

Some captive females have produced 100 young per year (Storer 1960). In urban mouse populations the average proportion of fecund females found pregnant during the year was 22% (Laurie 1946). Given such a potentially high reproductive rate one can see that for most indoor mouse populations various environmental factors must limit actual population increases. A female stops producing young about 15 months of age, but may live much longer. Males may live up to 3 years (Ebeling 1975).

An indoor population is limited by available food, shelter and competing species. Since rats are predaceous on mice as well as competitors for food and shelter, their removal often allows mouse populations to increase (Shenker 1973) because food and habitat previously taken by rats is now available. Thus, the previous presence of rats in a structure may be a prediction of a later infestation with mice.

TABLE 1.

COMPARING *MUS MUSCULUS* WITH OTHER RODENTS MISTAKEN FOR HOUSE MOUSE

OTHER RODENTS	HOUSE MOUSE
Young roof or sewer rat, *Rattus* spp.: head and feet large for its body; tail naked and longer or shorter but not equal to head and body combined.	Feet and head proportional to its body; tail is semi-naked and is as long as the body and head combined.
Deer mouse or white-footed mouse, *Peromyscus* spp.: white venter (underside), bicolored tail.	Venter (undersides) brown or gray; lacks distinct bicolored tail.
Meadow mouse or vole, *Microtus* spp.: body plump, short hairy tail, eyes and ears small in proportion to head.	Body more slender and smaller than vole, long tail, eyes and ears large in proportion to head.
Harvest mouse, *Reithrodontomys* spp.: grooved upper incisors.	Flat, notched (not grooved) upper incisor.

TABLE 2.

DISTINGUISHING COMMON RODENTS*

CHARACTERISTIC	NORWAY RAT	ROOF RAT	HOUSE MOUSE
Scientific Name	Rattus norvegicus	Rattus rattus	Mus musculus
Other Common Names	Brown, Wharf or Sewer Rat	Black, Ship, House Rat	--
Adult Weight	11 oz	7 oz	½ oz
Snout	blunt	pointed	pointed
Ears	small,short hairs	large, naked	large
Tail	dark above pale beneath	all dark	small all dark
Fur	brown with black, shaggy	gray to black, smoother	light brown to gray
Droppings	capsule-shaped	spindle-shaped	rod-shaped
Food Needs	1 oz/day	1 oz/day	1/10 oz/day
Water	free water	free water	from food
Climbing	can climb	active climber	good climber
Nests	mainly burrows	walls, attics, trees	near or within stored materials
Swimming	excellent	can swim	can swim
Litter size	8-12	6-8	6-7
Litters/year	7	6	8, up to 10

* Adapted from: Pratt et al. (1977); Pratt and Brown (1976); Howard and Marsh, (1974); Marsh and Howard (1977).

TABLE 3.

BASIC INFORMATION ON HOUSE MOUSE BIOLOGY*

CHARACTERISTIC	DESCRIPTION
Sexual cycle	polyestrus, every 4 days, all year
Size of litter	6.7, based on 9 field studies
Litters/year	up to 10, based on food available
Age at weaning	21 days
Gestation period	19-21 days
Age at mating	6-10 weeks
Life span	1-2 years, maximum 6 years

* From Berry (1970); Marsh and Howard (1977).

Once other species are excluded from consideration, the major factors limiting the size of mouse populations are food and shelter. Water is seldom if ever limiting since this species can fill its water needs from the food it eats, even dry cereals. This capability and its small size make *M. musculus* particularly well adapted for arid building interiors. In response to stress (e.g. excessive heat) it can induce a torpor or dormancy which conserves its physiological reserves, (Fertig and Edmonds 1969).

3. *Impact of House Mouse:* Mice damage food, clothing, documents and other human artifacts and structures by gnawing, urination and defecation. The damage to food stores from mice wastes is probably 10 times the damage attributed to direct feeding. Many fires of "unknown cause" may be due to mice (and rats) which chew through wires.

Although rigorous proof of the role and extent of involvement is unavailable mice have been implicated in a number of important human diseases (see Rowe 1966, and Table 4). Webber (1982) summarizes the information about the human pathogens transmitted by mice and rats, but unfortunately does not distinguish in all cases which species of rodent is implicated with which pathogen. Conclusive evidence linking mice to transmission of LCM virus has been documented (Webber 1982). This arenavirus virus causes Lymphocytic chorimeningitis, (LCM). LCM is one of the causal agents of acute aseptic meningitis which is known to have caused human deaths, although infections are usually mild. The route of transmission is probably respiratory through dust contaminated with mouse urine, contaminated food and drink, or by direct contact.

Surveys of mouse populations indicate that up to 69% are infected (probably chronic carriers) of LCM virus. The house mouse continues to be the major reservoir of this virus (Evans 1976; Webber 1982). This association alone justifies mouse control from a public health point of view, but the association with many other human pathogens indicates a potential hazard exists wherever mice come into contact with human populations, their pets or laboratory animals.

4. *Natural Enemies:* Outdoors *M. musculus* is preyed upon by owls, hawks, snakes, cats, coyotes and many other predators. Weber (1982) documents the many human pathogens which mice (and rats) transmit to humans, many of which also decimate mouse populations. The common house cat, *Felis cattus*, is a major house mouse predator in domestic and feral situations.

TABLE 4.

SOME MOUSE-IMPLICATED DISEASES OF HUMANS*

DISEASE	CAUSAL AGENT	TRANSMISSION
Bubonic plague	Yersinia pestis	infested flea, e.g. Xenopsyllus cheopis
Salmonellosis	Salmonellia spp.	contaminated food
Rickettsial pox	Rickettsia akari	by house mouse mite, Liponyssoides sanguineus
Lymphocytic choriomeningitis	LCM virus	contaminated food, dust on fecal particles
Ratbite fever	Spirillum minus	by bite
Tapeworms	Hymenolepis nana H. diminuta	droppings contaminated food
Favus, ringworm	Trichophyton schoenleinii	direct contact or from mites
Dermatitis	house mouse mite, L. sanguineus	bites humans
Leptospirosis, or infectious jaundice	Leptospira icterohaemorrhagiae	contaminated food, water, etc.

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* See Webber 1982, for a more comprehensive treatment of these and other mouse implicated diseases.

III HOUSE MOUSE MANAGEMENT

1. Population Monitoring Techniques:

Monitoring programs consist of an initial inspection followed by regular observations and record keeping. The objective of monitoring is to; discover damage or markings that indicate mouse presence, locate the mice, assess population density, detect modes of entry, harborage and sources of food, and to time and evaluate effectiveness of treatment activities.

In areas where food and grains are stored or where mice have been a problem in the past, preventative inspections should occur before actual mouse presence is observed in order to detect new infestations when population levels are low. The first sign of infestation is usually the sight of a mouse running across an open space. Other indications include droppings, nest material, gnawing damage, tracks or smudge marks. Signs of larger, more long-term infestations include frequent sightings of mice and the presence of urinating pillars, composed of collections of grease, urine and dirt.

If large infestations are suspected, particularly in large buildings such as warehouses, the most effective time to make initial inspections is at night when most mice are active. Use of a strong flashlight will aid in making visual estimates of populations. A characteristic musky odor of mice will help differentiate them from rats. Wet and dry stains of mice and rats fluoresce under a black light (as do other substances such as glue), and this technique may be helpful in determining presence and locations of mice.

It is difficult to make population assessments for the house mouse which probably accounts for the paucity of useful documented studies. The best and most accurate censusing technique is snap trapping (see Section III.3)

Records should be kept of trap catches to assist in evaluating relative population density as well as effectiveness of suppression treatments. Population density variations over time and among structures can be compared by calculating an index of the number of trapped mice per number of traps set per night e.g., 40 mice/100 traps/night = 40% (Marsh and Howard 1977).

Other methods for determining mouse presence and relative population densities include use of talc and direct feeding. Patches of talc can be spread out at various intervals throughout a building and monitored. The percentage of talc-covered areas containing mouse tracks can confirm mouse presence and indicate relative population size. These talc patches can be used both before and after a control operation to evaluate effectiveness.

Direct feeding can be used to assess populations also. This requires placing measured amounts of finely ground cereal in numerous locations throughout a building. Whole grains or chunk baits will be carried off and thus are not suitable.

Live trapping, or mark and release techniques generally are useful only for special research purposes. They are not recommended for an IPM program largely because of the extra time involved.

The frequency of monitoring by traps should be dependent on a number of variables including sightings of mice, mouse droppings or damage presumed to be mouse-caused, previous occurrence of mice in the area, known attractiveness of stored material to mice, time of year, etc. In areas where mouse presence is anticipated on a seasonal basis (e.g. in colder climates where mice migrate indoors during winter) monthly monitoring utilized during spring and summer should be increased to weekly during late fall. In areas where mice are a chronic problem, monitoring should probably occur weekly.

Inside structures, or in the area immediately ajacent to building foundations, the only important natural enemy of house mice besides humans is the domestic cat (see Section III.3). Observations of cat behavior can be useful when monitoring for mice since by their stalking and similar actions cats can indicate where new mouse invaders may be hidden.

. Threshold Action Population Level

Injury level refers to the point in the growth of the pest population when the numbers of pest organisms are sufficient to cause some unacceptable kind or degree of structural, economic, aesthetic or medical damage (injury).

Because of their potential to damage cloth, paper and other furnishings, to contaminate food stuffs and to cause fires by chewing on electric wires, the injury level for house mice inside a building is one mouse. The exception to this may be in structures without electricity or structures that do not contain materials that may be damaged or contaminated by mice. In such cases consideration should be given to the fact that providing this mouse harborage creates a potential hazard to nearby buildings.

The suspicion of mouse presence based on observation or reasoning should be sufficient to initiate periodic monitoring with traps. The confirmation of mouse presence, based on trap catches, mouse droppings or damage to stored materials, should be sufficient to initiate control methods, emphasizing habitat modification and physical controls.

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

a) design or redesign of the landscape, structure or maintenance for the purpose of reducing or eliminating the pest problem;

b) modifying the habitat in some major way to discourage the pest species;

c) human behavior changes including the alteration of use patterns or maintenance practices contributing to the pest problem, or education to increase tolerance levels for the "pest" species or the aesthetic damage it causes.

Preventive maintenance is the best and least expensive procedure, but is seldom used. Once a pest problem is present the life-supporting systems (particularly food and habitat) for the mice should be reduced in conjunction with removal of the mice themselves. If treatment actions are confined to mouse removal the habitat is left "open" for new invaders. Habitat modification alone still leaves existing mice free to produce damage. Thus, several suppression strategies must be combined.

Mouse proofing should be part of the original design of structures that will hold grain, seed or other human and animal foods. Where this has not been done modifications will have to be made later as a special effort. Perpendicular barriers of galvanized metal, 18-24" high, successfully excluded mice from grain piles during the great Australian mouse plagues (Winterbottom 1922).

The small size of mice makes mouse-proofing difficult. A fully-grown adult can squeeze through openings the size of a dime. Consequently, even small holes need to be searched out, stuffed with steel wool, covered with sheet metal, and/or filled with caulk, plaster or similar materials. Storage of foods, particularly grains, in tight-fitting metal or glass containers will reduce mouse access to these materials.

Spilled grains, seed or similar foods particularly attractive to mice should be thoroughly cleaned up and disposed of in mouse-tight garbage containers, or composted in hot, aerobic compost piles. Repairs to door sills and kick-plates, screens and other areas receiving continual wear should be made part of regular maintenance routines.

Information on the potential hazards from house mouse presence should be made available to both staff and visitors to counteract a frequent sentiment that domestic mice are cute and not worth controlling. This education could be particularly important where visitors occupy cabins under park jurisdiction and may feed mice for amusement.

Of the procedures available for suppression, trapping is the preferred method. Traps provide physical evidence of capture while baiting provides no such evidence and produces unpleasant odors from decaying carcasses. These carcasses may be attractive to dermestid beetles which destroy proteinaceous materials (e.g. wool, silk, fur). Simple snap traps which are widely available are effective, particularly if they have expanded triggers so they will snap when a mouse runs over them without attempting to reach for food.

Metal snap traps are available that have an opening or setting mechanism similar to that of a clothes-pin. Metal traps are long-lasting, particularly if lubricated and protected from rusting. These traps can be set quickly so many can be used at one time. The sensitivity of the trigger on the clothes-pin type traps also can be adjusted rapidly and easily. This is important since trapping mice requires the setting of large numbers of traps. The wire-spring type traps require moreltime and skill to set.

Table 5 lists common baits that have been shown to be effective for trapping house mice. Instead of food, a small piece of cotton may be attached to the trigger where the mice pull at it for use as nesting material. Cotton does not spoil as do other "food" baits. Trap shyness can be minimized by alternating different types of baits (see Table 5).

TABLE 5.

BAITS TO USE WITH SNAP TRAPS*

---

peanut butter mixed with rolled oats, wheat or canary seed
raisins
bread
cotton tied to the trigger

---

* From: Elton 1942; Schuyler and Sun 1974; Ebling 1975; Rowe et al., 1974; Frishman 1982.

Pre-baiting (where traps are left baited but not set) can be used to increase trap catches with heavily trapped or trap shy populations. Traps soiled with blood should not be cleaned since they are more effective than a clean, unused trap (Frishman 1982).

Successful trapping campaigns rely on large numbers of traps concentated in areas where mouse presence is suspected. Mice have relatively small home ranges so at least one trap every two to three linear feet is needed to insure capture. Snap traps should be placed at right angles to the runway rather than in line with it. This enables mice to be trapped when moving in either direction along the runway. Set traps out for two to three days and then move them to new locations. Continuous availability of traps over a long period of time "produces" mice that become trap-shy (Southern 1954). Also, small mice are seldom killed by snap traps and remain to re-establish the infestation at a later period. Thus monitoring at an appropriate frequency is recommended.

Traps should be handled infrequently and with gloved hands as mice can detect human odors left on the traps. New traps should be seasoned by burying in soil and grass to remove human odors. Metal traps used outdoors will last longer if coated with wax. They also require oil to keep the moving parts in working condition. Frishman (1982), recommends against the use of petroleum oils because they are repellent to mice. Lubrication with lard, other animal fat or bacon rinds will help prevent rusting and will help attract mice. Fitzwater (1970) also reviews the history of trapping and presents many practical suggestions on trap use.

Bateman (1973), has produced a general book on trapping which pictures and discusses many types of traps. Where large scale trapping programs are used markers and maps probably will be needed to enable workers to find traps easily and reduce trap losses. Numbers should be scratched into the metal or wood surfaces of the traps and records made of trap positions and numbers.

Traps that will capture more than one mouse at a time are available for use where mouse populations are high. However, these multi-catch traps all capture the mice alive. Frishman (1982) describes how to use these traps and indicates they are useful when placed outdoors near entrances to food processing establishments to catch mice before they enter the buildings. Traps can be immersed in water to kill captured mice. Such traps must be inspected and emptied every one or two days otherwise mice will cannibalize each other, creating odor and other problems. Wildlife managers or others may find these traps objectionable for this reason.

Glue boards, sticky box traps or tubetraps also can be used effectively in many locations. No data is available comparing efficacy of glue boards or boxes, with snap traps. However it is commonly known that glue traps catch small mice as well as large adults. (Rats are more difficult to capture with glue boards because they can sometimes pull themselves from the glue.) Such traps are easy to place but like snap traps require follow-up in order to prevent unsightly and odoriferous decomposition.

If glue boards are baited, the bait (e.g. peanut butter, jam, nutmeats, cake crumbs or sweets) should be placed in the center. Enclosed glue boards guard against moisture and dust, but may reduce the effectiveness of the board since mice are more cautious when entering an enclosed "new object". Keep boards in place for at least five days to allow mice to overcome initial shyness of the new object. Live animals stuck in the glue can be submerged until dead (NPCA, 1978). Some people regard glue boards as objectionable because they do not kill immediately. Also, if forgotten they can produce odors after death of a rodent.

Repellent sound devices have captured the imagination of consumers. No research is available to indicate their utility at this time. There is no information on their effects on other mammals. Any effects in repelling mice by such devices are likely to be short-lived if habitat modification also does not occur.

Dentition, stalking behavior, skeletal structure and stomach content analyses of the domestic cat, Felis cattus, indicate a high degree of adaptation specifically to killing house mice (Beadle, 1977). However, depending on the individual cat, they also will catch small reptiles, ground-nesting birds and insects. Therefore, outside of highly urbanized areas where they primarily patrol building interiors such as warehouses, their impact on wildlife may be detrimental.

4. Management Alternatives - Chemical:

Suppression of large mouse populations with chemical controls should be secondary to trapping with snap or sticky traps. However, where trapping or physical changes have been shown to be ineffective, chemical controls may be used. Baits containing Chlorophacinone or Fumarin are the chemicals recommended for NPS use.

Some poison-containing baits used for rat control (except red squill and norbormide) also can be used against mice. However, because mice nibble rather than eat large quantities at a time, a higher concentration of the poison is needed (Ebeling 1975). This requires proportionally more care by the pest control operator to prevent exposure of poisons to humans, pets and wildlife, particularly with single dose materials like zinc phosphide.

Because they are less hazardous to humans and wildlife the multiple dose anticoagulant poisons are preferable for house mouse control. These anticoagulants prevent blood clotting, causing rodents to bleed to death internally. An attractant or bait (usually a food item), is the key to the anticoagulant formulation since it both masks the poison and attracts the rodent. To prepare impregnated baits, an acceptable solvent is needed. Glycerine, corn, arachis and mineral oils were found to be more palatable than olive, linseed or cod-liver oil, see Rowe et al. (1974).

The multiple-dose anticoagulants, i.e. Warfarin, Chlorophacinone, and Fumarin are relatively safe for the operator and other humans. However, widespread resistance to warfarin has developed (see Kaukeinen 1979, for a list of references to anticoagulant resistance).

The warfarin-resistant micehave also shown resistance to chlorophacinone and tolerance to the newer single-dose anticoagulants, brodifacoum and bromadiolone. The rapid development of cross-resistance to these newer single-dose materials is significant. Frishman (1982), summarizing data provided by S.C. Franz indicates that in some areas of the U.S. (e.g. Buffalo, N.Y.) resistance to warfarin within some house mouse populations exceeds 75%. One can expect mouse resistance to follow the pattern already well-documented by the <u>Rattus</u> spp., i.e. house mice will become more difficult to control as resistance becomes more widespread.

Resistance to baits should be suspected if bait blocks (i.e. poison in parafin blocks, bait packages or loose bait regularly is eaten without a corresponding reduction in mouse sighting, holes or other signs of mice presence (see Howard and Marsh 1981). Laboratory verifications of resistance is the best procedure to use in evaluating the extent of resistance in a local population (Franz 1979).

The use of traps alone or in conjunction with poisons increased emphasis on preventative habitat maintenance and habitat alterations will help extend the useful life of existing poisons. Efforts to make existing poisons or poisoning procedures more effective also may reduce the speed of resistance development.

Bohills et al. (1982) present the results of studies to evaluate the design of mouse bait boxes. Bait boxes offer advantages over broadcast delivery systems because the bait is protected from the elements and inadvertent human and pet exposures. Also, the amounts taken can be monitored more accurately. These authors also indicate that the use of boxes significantly increases the take of food. By exposure to greater amounts of the toxicants per unit of exposure, marginally susceptable rodents are eliminated from the breeding population. However useful in the short term, such approaches do not directly address the problem of developing resistance.

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

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NATIONAL PARK SERVICE
IPM Information Package

POISON IVY

Final Report

February 1984

Submitted To:

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

Submitted By:

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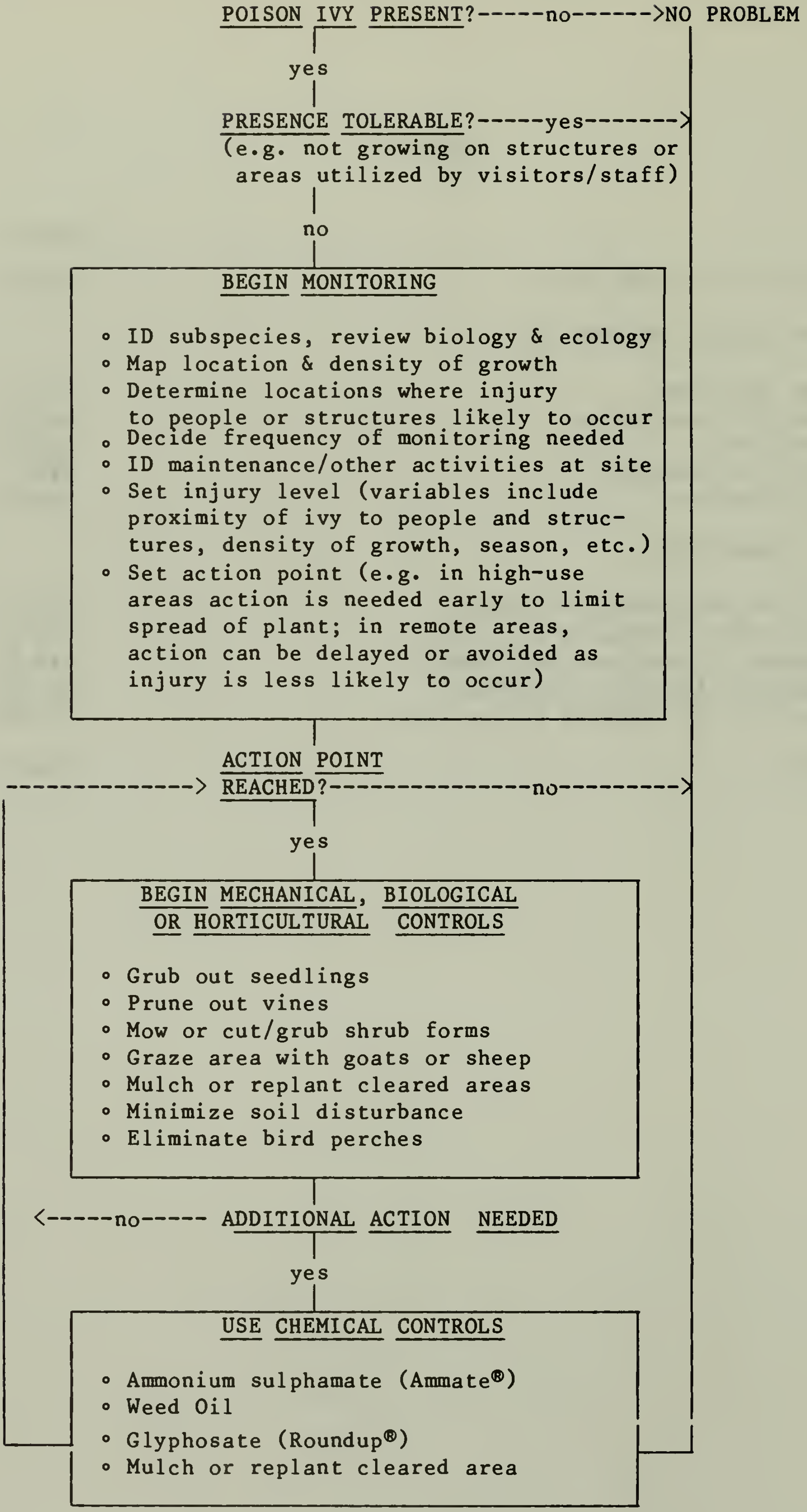
CONTENTS

I POISON IVY IPM DECISION TREE



POISON IVY PRESENT?-----no------>NO PROBLEM

yes

PRESENCE TOLERABLE?-----yes------->
(e.g. not growing on structures or areas utilized by visitors/staff)

no

BEGIN MONITORING

- ID subspecies, review biology & ecology
- Map location & density of growth
- Determine locations where injury to people or structures likely to occur
- Decide frequency of monitoring needed
- ID maintenance/other activities at site
- Set injury level (variables include proximity of ivy to people and structures, density of growth, season, etc.)
- Set action point (e.g. in high-use areas action is needed early to limit spread of plant; in remote areas, action can be delayed or avoided as injury is less likely to occur)

-------------> ACTION POINT REACHED?---------------no--------->

yes

BEGIN MECHANICAL, BIOLOGICAL OR HORTICULTURAL CONTROLS

- Grub out seedlings
- Prune out vines
- Mow or cut/grub shrub forms
- Graze area with goats or sheep
- Mulch or replant cleared areas
- Minimize soil disturbance
- Eliminate bird perches

<-----no----- ADDITIONAL ACTION NEEDED

yes

USE CHEMICAL CONTROLS

- Ammonium sulphamate (Ammate®)
- Weed Oil
- Glyphosate (Roundup®)
- Mulch or replant cleared area

II BIOLOGY AND ECOLOGY OF POISON IVY

1. *Species Described*:

Poison ivy is a member of the Sumac family, Anacardiaceae, which also contains such familiar plants as Poison oak (*Rhus diversiloba*) and Poison sumac (*R. vernix*), the cashew nut tree (*Anacardium occidentale*), and the lacquer tree of China and Japan (*Toxcicodendron verniciflуum*) from which oriental lacquerware is made. The sap in each of these species contains urushiol which can cause severe dermatitis in susceptible humans.

Poison ivy (*Rhus radicans* L., or *Toxicodendron radicans* Kuntz) is a deciduous woody perennial plant which is native to North America. It takes several forms including a trailing vine, a subshrub to shrub from 2 inches to 4 feet high, or a vine up to 50 feet tall

Leaves are 1/2 to 2 inches long, and are always borne in groups of three leaflets. These leaflets, found alternately along the stem, may be glossy or dull-green, are usually smooth, but occasionally may be somewhat hairy. The edges of the leaves vary widely, some are smooth, others are toothed or even deeply lobed. Unfurling leaves are red, becoming green during summer and colored various shades of yellow, orange, red or bronze in autumn.

Leaves of poison ivy never occur in pairs along the stem. This "alternate" leaf characteristic distinguishes poison ivy from other, more benign plants such as Virginia Creeper, *Parthenocissus quinquefolia* L., See Table 1 for details which distinguish poison ivy from plants which resemble it.

Stems are woody, ranging from ½ to 6 inches in diameter Slender, creeping rootstalks are produced from the base of the stem. These roots often travel horizontally on top of or through the soil, giving rise to short, slender leafy shoots several yards from the parent plant.

In early summer, small clusters of greenish-white flowers form where the leaf and stem join. Flowers develop into white or cream-colored berries about 1/8 inch in diameter. The berries are especially helpful in identifying poison ivy during the winter.

Consistent variation in the appearance and growth habit of poison ivy is recognized by the designation of certain subspecies. See Table 2 for a description and geographical distribution of the major subspecies of poison ivy.

TABLE 1.

DISTINGUISHING POISON IVY FROM PLANTS WHICH RESEMBLE IT

RELATED SPECIES	POISON IVY
Virginia Creeper (*Parthenocissus quinquefolia*) has leaves composed of five leaflets; leaf scars are circular with raised edge; fruits are juicy and purple; aerial roots contain suction disks.	Leaves are composed of three leaflets; leaf scars are triangular; fruits are hard and white; no suction disks on aerial roots.
Boston Ivy (*Parthenocissus tricuspidata*) has leaves with three lobes but rarely three leaflets; leaves are up to 8" wide; fruits are juicy and purple; aerial roots contain suction disks.	Leaves are composed of three distinct leaflets; leaflets are narrow, rarely exceeding ½ inch in width; fruits are hard and white; no suction disks on aerial roots.
Box Elder (*Acer negundo*) has leaves composed of three leaflets but are borne opposite each other on the stem; fruits are in flattened pairs with "wings"; young stems are bright green.	Leaves composed of three leaflets borne alternately on the stem; fruits have a round, berry-like shape; young stems brown or dull green.

2. Geographic Distribution: Poison ivy is widely distributed in the United States. Table 2 provides a description and gives the distribution of the four subspecies of poison ivy.

3. Life History: Poison ivy has male and female flowers on separate plants (dioecious). Pollen is distributed by insects and female flowers produce a high percentage of one-seeded mature fruit (Mulligan 1977). Seeds mature in late summer or early fall. They may remain viable for at least six years (Gillis 1971).

Few seeds fall directly to the ground, remaining instead encapsulated in the fruits which are eaten by birds and other wildlife.

Poison ivy also reproduces from alternate buds on horizontal rootstalks. However, horizontal spread of poison ivy is slow, rarely more than 4 inches/year and frequently less (Mulligan 1977). However, vertical growth of vining stems is rapid. Despite its ability to propagate vegetatively, poison ivy rarely becomes established by plant fragments (Gillis 1971).

Colonization of new sites is primarily by seed dispersed by birds and animals during autumn, winter and early spring. The hard seeds pass through the digestive tracts of birds and animals in a viable condition.

Seeds germinate when the soil warms up in the spring. They produce a primary vertical stem and basal roots. Horizontal rootstalks (rhizomes) are produced from the base of the primary vertical shoot in the first or second growing season, and grow horizontally on or beneath the surface of the ground. Rhizomes have buds which produce new vertical stems as well as adventitious roots just below each bud. Each new vertical stem in turn produces additional horizontal rhizomes, resulting in a large interconnected clone with many vertical stems and horizontal rootstalks, both above and below ground.

Flower and leaf buds are formed on new growth on vertical stems in late summer and early autumn, and are carried overwinter on the stems. Flower buds formed the previous year open in late spring through mid-summer, depending on location. Maximum flowering occurs in June and July in most areas with some additional flowering occuring sporadically until early autumn.

TABLE 2. MAJOR SUBSPECIES OF POISON IVY FOUND IN THE UNITED STATES

Latin Name	Description	Distribution
Rhus radicans L. subsp. *radicans* (*Toxicodendron radicans* subsp. *radicans* Green, Mulligan.)	Shrub to vine form with aerial roots climbing rough surfaces; undersurface of leaflets with tufts of hairs toward bases of midribs; hairs ascending along lateral veins on undersurface of leaflets; usually 5 or more leaves on vertical stems; leaflets entire or mostly entire; surface of fruits pubescent.	A lowland subspecies which is essentially an Atlantic coastal dweller that occurs from southern Nova Scotia south to the Florida Keys and the western Bahama Islands and west to eastern Texas. It is separated from subsp. *negundo* to the west by the Allegheny Ridge in PA. and NY., and the Blue Ridge mountains to the south. In the north *R. radicans* is separated from *R. rydbergii* along the 44th parallel of latitude.
R. radicans L. subsp. *negundo* (T. *radicans*, subsp. *negundo* Greene).	Shrub to vine with aerial roots climbing rough surfaces; hairs along midrib on undersurface of leaflets not tufted; hairs along sideveins on undersurface of leaflets spreading; usually 5 or more leaves on vertical stems; leaflets toothed or mostly toothed.	Found in the central area of the U.S. (the midwestern states generally north of the Ohio River). Eastern boundary is Allegheny Ridge, most clearly delimited in the vicinity of Tuscarora Mountain in Pennsylvania. On the east flank of the Alleghenies is subsp. *radicans*.
R. radicans L. subsp. *rydbergii* (*T. radicans*, subsp *rydbergii* Greene)	A trailing vine, or a subshrub to shrub lacking aerial roots; hairs along midrib on undersurface of leaflets not tufted; hairs along sideveins on undersurface of leaflets spreading; usually fewer than 5 leaves on stems; leaflets toothed.	Most widespread and uniform of all the subspecies. Occurs from Central Arizona to the Gaspe Peninsula and to the Rockies in southern Canada.
R. radicans L. subsp. *verrucosum* (*T. radicans* subsp. *verrucosum* Greene)	Aerial roots; glabrous leaves and shoots except for an occasional population with small tufts of hairs in major vein axils on lower leaflet surface. Has become distinctive due to prominent sharp lobes on the leaflets.	Found only in Texas.

The vine form of poison ivy is the most common form and may grow to several inches in diameter and become woody. Slender vines may run along the ground, grow with shrubbery, or take support from a tree.

The vine forms roots readily when in contact with the ground or with any object that will support it. Aerial roots attach the vine securely to the tree or post. According to Crooks and Klingman (1967), the vines and roots apparently do not cause injury to trees except where growth may cover the supporting plant and exclude sunlight. The vining nature of the plant makes it well adapted to climbing over stone walls or on brick and stone houses. See Section II.2 for a discussion of the impact of poison ivy vines on buildings and other structures.

4. Hosts/Site Information:

Poison ivy is usually found where soils have been repeatedly disturbed. It does not grow where repeated agricultural cultivation occurs, since these operations remove seedlings before they can become well-established. Poison ivy grows in association with many other native and introduced plants and is most often found growing at woodland edges or openings, along roadsides and fenceposts, and adjacent to watercourses. Because poison ivy fruits are eaten by a wide variety of birds, the plant is common around trees, fencerows, under telephone wires, and wherever birds are likely to perch.

Its wide distribution throughout the north-and southeastern U.S. and extensions into Canada and south into Central America indicates that poison ivy is adapted to a wide variety of climatic conditions.

Poison ivy grows on a variety of soils. According to Gillis (1971), calcium is the most important element in the soil for the growth of poison ivy. The maximum root development is in the A horizon of the soil and poison ivy is virtually absent from soils that are highly leached of minerals, especially calcium and magnesium.

As a colonizer of disturbed soils, poison ivy appears to play a significant role in erosion control and soil stabilization. In the Friesland Province of Holland, poison ivy is used to stabilize dykes (Gillis 1975). In park settings, poison ivy (properly posted with signs) could be used to discourage human trampling of sensitive areas.

5. Natural Enemies:

Mulligan (1977) lists arthropods in the following orders as feeding on poison ivy: Lepidoptera, Hymenoptera, Diptera, Coleoptera, Homoptera (Aphididae) and Acarina (Harrison 1904; Tissot 1928, 1933; Steyskal 1951; Gillis 1971; Richards 1972). Criddle (1927) considered the larvae of Epipaschia zelleri Grote (Lepidoptera) the most destructive of all insects to poison ivy.

Conners (1967) lists the following fungi as infesting poison ivy in Canada: Cercospora rhoina Cke. & Ell. Man., Cylindrosporium irregulare (Pk.) Dearn., Cylindrosporium toxicodendri (Ell. & Mart.), Phyllosticta rhoicola Ell. & Ev., and Pileolaria brevipes Berk. & Rav. Parmelee and Elliott (1974) also list Pileolaria brevipes from British Columbia and Arthur (1934) states that this rust infects poison ivy throughout its range.

Fruits are eaten by many birds. Martin et al. (1951) report that poison ivy fruits make up a quarter of the diet of some flickers and wrentits. Fruits, stems and leaves are eaten by bears, muskrats, rabbits, small rodents and deer, and a number of small mammals use it for cover. Bees can make a nontoxic honey from its nectar (Rostenburg 1955).

III POISON IVY MANAGEMENT

1. Population Monitoring Techniques:

The environmental conditions conducive to poison ivy growth (e.g., sites where soils have undergone severe disturbance) should be monitored several times per season in order to spot new infestations of the plant. Examples of such areas include construction sites, trenching operations, heavily used trails, eroding streamsides, and even rodent mounds. Monitoring of these areas can consist of casual observation until poison ivy is found to be present, at which point written records should be initiated.

Begin monitoring in mid-to-late spring when new seedlings have germinated and the leaves have opened on older, established clumps. Use the distinctive 3-part leaves to identify the plant. To decide on levels of effort needed for monitoring, determine which growth form of poison ivy is present at the site. With the relatively low shrub forms which tend to spread horizonally only very slowly -- approximately 4" per year (Mulligan 1977), monitoring can be kept to a minimum.

The most important thing is to time the first monitoring visit(s) early enough in the season that both seedling and established poison ivy stands are visible and can be accurately noted on a map. This is usually mid-to-late May in most parts of its range.

For the vining forms of poison ivy which are capable of rapid and extensive vertical growth (six to twenty feet in one season is not unusual), more frequent monitoring might be desirable in order to determine the need for treatment before growth is excessive. Since most vertical growth of poison ivy occurs prior to flowering, it is desirable to monitor poison ivy vines once per month between foliation in the spring (April-May), and onset of flowering (June-July in most areas) and again at the end of the growing season.

If monitoring indicates that no treatment is required, subsequent visits should be necessary only at the end of the summer before plants lose their leaves. At this time any changes in park use patterns near the poison ivy, as well as the height and width of the clump can be recorded. By reviewing monitoring data park managers can determine relative growth rates of poison ivy in their area as well as the likelihood of park visitors or workers coming in contact with it. Decisions about injury (tolerance) levels and treatments can be based on this data.

If a treatment is warranted, monitoring must occur frequently enough to determine when the plants are at the optimal stage for treatment. For example pruning treatments on poison ivy are most effective if applied just before the plant blooms; herbicide treatments on mature plants should be applied during or just after flowering (see section III.4). Since chemical and mechanical treatment methods prescribed for poison ivy usually require more than one application, it is important that monitoring occur frequently enough after the first treatment to detect if and when a second treatment is needed.

This usually means that treated plants should be visited again a minimum of two-to-four weeks after initial control efforts. If a second treatment appears to be needed, another post-treatment monitoring visit should be scheduled. A final visit at the end of the growing season should be conducted to determine the overall effectiveness of the treatment program. Plants believed to be dead sometimes resume growth after many months; thus an area under treatment must be watched closely for at least a year to determine if retreatment is necessary (Crooks and Klingman 1967).

As a native plant, poison ivy tends to enjoy a stable relationship with the herbivores and pathogens that feed on it. Thus, suppression of its growth by native natural enemies is not likely to be significant.

2. Threshold/Action Population Levels:

Injury level refers to the point in the growth of the pest population when the numbers of pest organisms are sufficient to cause unacceptable structural, economic, aesthetic or medical damage (injury). When applying the injury level concept to weed problems, it is useful to substitute the phrase "tolerance" levels as a synonym for "injury" levels.

Several variables should be considered in establishing any weed tolerance level. These include:

a. species and growth habit;
b. location of weed problem;
c. weed population size;
d. type of actual or potential damage caused by weed;
e. degree of invasiveness of growth;
f. costs of managing the weed problem (including lost work time, responding to complaints, education of staff and visitors, etc.).

These variables may differ from site to site depending on the location, overall maintenance objectives, role or value of the plants in the environment, opinions and experience of managers, level of complaints by visitors or staff, etc. In the case of poison ivy, the adverse health effects that contact with the plant pose to humans usually render tolerance levels very low.

Similarly, the potential damage to buildings posed by poison ivy may also justify low tolerance levels. Like Boston Ivy (Parthenocissus tricuspidata) and English Ivy (Hedera helix) (Warnock et al. 1983), Poison Ivy attaches to stone masonry, wood and other building materials by means of aerial rootlets which are capable of penetrating and enlarging small cracks in the structure. This habit can result in water damage and general weakening of the building. The dense foliage and thicket of roots produced by poison ivy also can visually obscure the building surface so that damage goes undetected.

Tolerance for poison ivy growing on trees, however, may be high due to the fact that vines and roots apparently do not cause injury to trees except where growth may cover the supporting plant and exclude sunlight (Crooks 1967).

In summary, in areas of high use near buildings, within campgrounds, and on major trails, tolerance levels would be low since the likelihood of human contact or damage to buildings is high. In low use and remote areas of the park, tolerance levels for poison ivy could be quite high, since human contact is less likely. In general, poison ivy should only be controlled in developed sites where the plant is likely to come in contact with humans or damage structures.

. Management Alternatives Non-Chemical

A. Indirect suppression: This approach attempts to change the conditions that create or define the pest problem. Examples are:

a) design or redesign of the landscape or the plant care system for the purpose of reducing or eliminating weed growth;

b) modifying the habitat in some major way to discourage growth of a particular weed species;

c) human behavior changes including the alteration of use patterns or maintenance practices contributing to weed growth, or education to increase tolerance levels for the "weed" species.

Poison ivy is primarily a problem in landscapes or areas that have been left to revert to a more "natural" state after previous human management. Redesigning the area is rarely a desirable strategy because of the basic objective of keeping the area as "natural" as possible.

However, in developed park areas designers of latrines, visitor centers, campgrounds, fencelines, etc. should be encouraged to avoid creating bare areas beneath likely bird perches as these conditions optimize the establishment of poison ivy.

No examples of using habitat modification to manage poison ivy could be found in the literature. However, ecological information on the pest suggests that application of deep mulches to bare soil could restrict germination of poison ivy seeds (See Section III.3

Where significant soil disturbance has occured it is important to seed in or plant fast-growing soil colonizing plants such as grasses or groundcovers in a effort to limit the soil space and nutrient reserve otherwise available to poison ivy. Although this tactic has not been documented specifically in the weed literature for poison ivy, it is a well-established weed control tactic for similar species (Daar, 1983b) and is worth testing on poison ivy.

To be most effective, the planting should occur as soon as possible after the soil disturbance has occured. Native plant species should be used whenever possible Consult local soil conservation and native plant organizations for recommended plant species.

In a park setting, it is important to educate visitors and staff on methods of identifying poison ivy so they can avoid contact with the plant. To the degree human contact with the plants can be avoided, treatments of the pest will be unnecessary. Signs, pamphlets and displays can be located at trailheads, campgrounds, visitor centers and similar areas where visitors are frequent.

B.Direct supression: This approach focuses on the pest and in the case of poison ivy several physical controls are available but biological controls are limited.

1. Physical controls:

a. Grubbing out

Seedling: Physical removal of poison ivy with digging and cutting tools is often the most effective means. Seedling plants can be dug out most easily in early spring after leaves have unfurled, but while the soil is still wet. By summer or fall of the first year, seedlings usually have a well-developed vertical and horizontal root system and are more difficult to remove.

Mature Plants: Late fall, after poison ivy has dropped its leaves and rains have saturated the soil, is usually the best time to dig out mature poison ivy. Since root systems may travel horizontally for 20 feet, extensive digging may be necessary. However, the roots do not appear to grow more than a foot or so deep, so extensive vertical digging is usually not required. After the initial grubbing has occured, treated areas should be monitored on a monthly basis to check for resprouts from rootstock inadvertently left in the soil.

In addition to shovels and mattocks, other tools useful when grubbing out poison ivy include brush hooks, McLeods (a double-edged digging tool), Pulaski's (a forester's axe), and gas-powered weedeaters with blade attachments. Hydraulic winches mounted on pick-up trucks are often useful in removing stems and roots of poison ivy growing in dense thickets.

b. Mowing

Seedling and young plants can be kept within an inch or two in height by frequent mowing (probably twice per month during the growing season). This regular removal of leaves and stems will restrict (but not eliminate) the development of horizontal roots. If a mowing program is adopted, it is important to collect clippings and dispose of them in a plastic bag or bury them to prevent the clippings from being spread over large areas and inadvertently contaminting park workers or visitors. If the plants are established clumps supported by mature rootstalks mowing should be done just before the plants bloom. Mowing is not recommended for poison ivy control in a lawn area used for picnicing or other recreational activities.

c. Cultivation

Poison ivy can be removed by repeated cultivation with a hoe, disk, spring-toothed harrow, or duck-foot cultivator. To be effective, cultivation has to occur frequently enough to remove new seedlings or young plants before they are able to form extensive perennial roots.

The actual cultivation frequency required is a function of several factors including extent of growth of poison ivy, soil conditions, type of adjacent vegetation, etc.

d. Girdling and Pruning

It may be possible to kill poison ivy by girdling stems or trunks. To do this, cut a band through the bark into the sapwood around the circumference of the stem. The incision cuts the sap transport vessels thus halting the movement of nutrients and water up and down the plant, causing eventual death.

Poison ivy growing as long vines on trees can be killed by severing their stems near the soil line with an axe or saw (Grant 1929). To minimize damage to the tree bark, the final cut should be made with a knife.

The severed vine can be pulled from the tree at the time the cut is made, or it can be left to dry on the tree over the summer and be removed in the fall when the dried leaves have dropped off and the remaining wood is less toxic to handle. After a month or six weeks, the new tops that spring from the inground portion of the stem may be pulled up (Grant 1929), injected or painted with an herbicide, or cut off repeatedly in hopes of starving the root system and achieving the eventual death of the plant.

e. Mulching

Once poison ivy has been removed from an area, it is desirable to cover the soil with a temporary groundcover to reduce the ability of poison ivy seedlings to recolonize the open ground. A deep mulch (6 - 12 inches) of hardwood chips is most likely to provide protection against poison ivy seedling emergence. Hardwood chips in the 1" x 2" size range are more effective than mulches made from bark. The smaller sizes of bark mulches and their easy decomposition by soil microbes limits their effectiveness.

NOTE: Never burn any part of the poison ivy plant. Tiny droplets of the oil will be carried on ashes in the smoke and can be breathed into the lungs. The throat may swell and the whole body can break out in an extreme rash. Whenever possible, dispose of poison ivy by burying. Plant pieces should be covered with at least 12" of soil to prevent sprouts from developing. If burying is not feasible, enclose plants in plastic bags for disposal in a landfill.

f. Biological control

A number of arthropods, micro-organisms and viruses are reported to feed on poison ivy (See Section 1.4). However, researchers are reluctant to pursue biocontrol programs on poison ivy because so little is understood about the beneficial roles played by this native plant The unknown risks to the environment caused by non-selective suppression of native plant species by biological control organisms could outweigh the benefits.

Suppression and even eradication of shrubby stands of poison ivy can be achieved by intensive grazing of livestock in areas where the plant is growing (Grant and Hansen 1929). Goats eat both foliage and stems of poison ivy. While few studies exist on using livestock specifically for poison ivy control, there is extensive experience with goats controlling similar brush species such as poison oak (*Rhus diversiloba* L.) in the western U.S., and useful extrapolations to poison ivy are probably in order (Daar 1983a; Green and Newell 1982).

Where appropriate, Angora, Spanish or other non-dairy goat breeds or sheep can be concentrated in an area containing poison ivy. A lightweight, portable, electrified plastic fencing called Flexinet® has been developed. It is powered by a 12 volt car battery or solar cell which generates sufficient current to keep livestock in and predators out. Fencing fabric is supported on non-conductive fiberglass fence posts. Flexinet® is available from the Waterford Corporation, Fort Collins, CO and in 1983 costs were approximately $100 for 150 feet .

The degree to which poison ivy is suppressed or eradicated by goats or sheep depends on a number of factors including herd size, duration of penning, state of succulence of vegetation, etc. Goats and sheep will graze or trample most of the vegetation in the area in which they are penned. Therefore, valuable vegetation such as specimen trees and shrubs should be protected by fencing or other barriers to keep the livestock at a distance.

Management Alternatives Chemical:

Since both shrub and vining forms of poison ivy usually grow in association with desired ornamental or native plant species, great care must be taken not to permanently damage such plants when using herbicides on poison ivy.

Typically, at least two herbicide applications are needed to kill all parts of the plant (Grant and Hansen 1929; Crooks and Klingman 1967). Seedlings should be treated in the spring as soon as new leaves are fully opened

(Daar 1983b). Translocated herbicides such as ammonium sulphamate (Ammate®) or glyphosate (Roundup®) should be applied on mature plants during or just after the bloom stage. This is the point when sugars are being translocated to the roots and will carry the herbicide throughout the plant system. If monitoring indicates retreatment is needed, a second application is best made as soon as resprouted leaves are fully expanded (Crooks and Klingman 1967). See Table 3 for a list of herbicides registered for use against poison ivy.

To keep damage to desirable plants to a minimum, use injection, frill or basal spray techniques where possible. Herbicide injection tools are available from forestry supply catalogues or other equipment sources. Frill methods consist of making shallow axe cuts around the circumference of the stem and applying herbicides into the cuts. Basal sprays involve coating the bark on the lower 12" to 24" of trunk or stem with herbicide.

When foliage sprays are required, spray nozzles which produce fairly large herbicide droplets should be used to limit drift of the herbicide. It may be useful to include an anti-drift product in the spray tank. Drift also can be minimized by using moderate pressure thus producing relatively large spray droplets, rather than high pressure which produces a driving mist (Crooks and Klingman, 1967).

Another application tool useful in confining herbicides to the target weed (spot-treatment) is a wick applicator. These tools absorb the herbicide on a rope, sponge or carpet wick and permit the applicator to wipe the herbicide directly onto the poison ivy. The applicators are made from common PVC plastic pipe and commercial rope, sponges or carpet pieces. They can be custom designed (or easily retrofitted) with long handles allowing the worker to stand some distance from the poison ivy yet still apply the herbicide. Manufactured, hand-held or machine-mounted wick applicators can be purchased from commercial sources.

The "jar method" is another technique of limiting drift. To implement this method, cut the tip off a trailing stem of the poison ivy plant. Discard the severed tip and place the cut end into a quart jar containing an herbicide solution for at least one hour. Jars (or other containers) should be stabilized so they don't tip over. It also may be necessary to use a wedge or fastener to hold the immersed shoot in position. The herbicide will be translocated throughout the plant's vascular system and the plant (or substan-tial portions) will die.

TABLE 3.

A COMPARISON OF EFFICACY, TOXICITY, MOBILITY & PERSISTENCE OF COMMON HERBICIDES USED AGAINST POISON IVY[*]

HERBICIDE	EFFICACY	TOXICITY (LD_{50})[†]	MOBILITY	PERSISTENCE SOIL/WATER[††]	COMMENTS
Ammonium Sulphamate (Ammate®)	H	L	L	S= 4-12 wks W= nd	Degrades to nitrogen and sulfur in soil
Aminotriazole (Amitrol-T®)	H	M	M	S= 7 weeks W= 201 days	Potentially carcinogenic in humans[¶]
Glyphosate (Roundup®)	H	L	L	S= >8 wks[§] W= nd	
Sodium Chlorate (Chlorate/Borate mix is fire-retardant)	H	L	L-H	S= 12-52 wks W= nd	

[*] Herbicides from Herbicide Handbook. 1979. Weed Science Society of America.

[†] Ibid, Herbicide Handbook.

[††] Pimentel, D. 1971. Ecological Effects of Pesticides on Non-Target Species. Office of Science and Technology. USGPO. NOTE: This data is dependent on many variables including soil type, available moisture, rates of application, etc. Figures presented here should be considered approximations.

[¶] IARC monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans, Supplement I, 1979. IARC, Lyon, France, p. 22.

[§] Herbicide Handbook, op.cit., p. 226.

KEY:

Efficacy:	H = High; M = Medium; L = Low
Toxicity:	H = LD_{50}'s of 1-99 mg/kg; M = 100-1000; L = >1000.[*]
Mobility:	H = High; M = Medium; L = Low
Persistence:	S = soil; W = water; nd = no data

Tl½

The herbicides ammonium sulphamate, sodium chlorate or glyphosate can be used in the jar method. Use at the highest concentration permitted on the label.

Bates (1955) found that a 40 percent concentration of sodium chlorate was more effective at killing woody plants than were weaker solutions of 5 to 10 percent. Note that sodium chlorate is highly combustible and should be used with extreme caution.

The "jar" method works on the principle of negative root pressure and, according to Bates (1955), the best results are obtained in hot dry weather and at the height of summer. Treatment with the "jar" method in mid-winter and early spring seem to be the least effective and treatment of certain plants was without effect in late March, but rapidly effective in July. Once the plant is dead, the sodium chlorate, "does not appear to cause any injury when the weed decays. Whether this is due to the small amount present or whether it is due to the decomposition of the chemical, is not known (Bates, 1955). Ammonium sulphamate degrades to the fertilizers nitrogen and sulphur. If the "jar" method is used, workers must remain near the jars to insure that visitors, pets or wildlife do not come in contact with the poisons.

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

5. Precautions for Handling Poison Ivy:

Poison ivy is toxic at all stages of growth--and even when dead from severed roots or herbicide spray (Crooks and Klingman 1967). Thus protective clothing should be worn no matter which treatment is selected. Workers should cover as much of the body as possible. Canvas or leather leggings over workpants provide extra protection when working in dense stands of the plants. Hands should be protected with thick canvas, rubber or leather gloves.

A beekeeper hat with veil can be used to protect the face when clearing dense stands of poison ivy. An industrial respirator mask should be worn when chopping or sawing plants to prevent breathing in sawdust particles, or when in the vicinity of burning poison ivy (burning is not a recommended method of control or disposal.)

Poison ivy sap can adhere to clothing, tools, and the coats of pets and livestock for very long periods of time, and therefore serve as reservoirs for recontamination. For example, Shelmire (1941) reports that gloves stored at room temperature for 16 months still can cause poison ivy dermatitis. Thus it is important that clothing worn while working in or near poison ivy be carefully removed (use gloves), washed in hot, soapy water, and hung in the air to dry for several days in order to insure that all sap is deactivated (Gillis 1975). Repeated washing may be needed. Do not wash with other clothing. Using rubber gloves, clean tools after each use with a rag containing an oil solvent such as gasoline, alcohol, or turpentine. Rags and gloves should be enclosed in a plastic bag and discarded after use to prevent contamination.

Contaminated skin should be washed several times with water and a strong soap. The soap dissolves the oily sap and enables it to be removed from the skin. If soap is not available, cotton balls soaked in vinegar (2 tablespoons in 1 cup water) or alcohol (1/2 cup alcohol to 1/2 cup water) can be dabbed on the contaminated skin to dissolve the sap. Calamine lotion or a paste of baking soda can be topically applied to the dermatitis to relieve itching.

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NATIONAL PARK SERVICE
IPM Information Package

RATS

Final Report

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Submitted To:

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CONTENTS

I. RAT IPM DECISION TREE

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

Start

↓

What is your rat problem?

------ → Rats are indoors → Go to page XXVII-

↓

Rats are outdoors

↓

Learn basic rat biology and identify rats

↓

Make initial day and night site visits to all outdoor areas
Look for signs of rat presence: burrows, pathways, droppings, signs of feeding, dead and live rats, smudge marks, etc.

↓

Monitor rats by hole count method, trapping, feeding rates, tracking powders, signs of rat activity, etc.

↓

Set injury level and action threshold.
In this case both are equal to 1 rat or 1 rat sighting.

↓

Modify habitat and by sanitation and reduction of cover.
Continue monitoring.

↓

Continue monitoring for program evaluation.

↓

If rats are still present, use Rozol or Fumarin.

↓

Continue monitoring for program evaluation.

Rats are indoors

↓

Learn basic rat biology and identify rats

↓

Make initial day and night sight visits to all indoor areas.
Look for signs or rat presence: holes, gnawings, smudge marks, droppings,
live or dead rats, signs of feeding, etc.

↓

Monitor rats by trapping, feeding rates, tracking powders,
signs of rat activity, etc.

↓

Set injury level and action threshold. In this case both are
equal to 1 rat observed or sign of active rats.

↓

Modify habitat by reduction of habitat, water and food.
Begin trapping. Rat proof buildings and secure all entry points.
Continue monitoring.

↓

If rats are still present, use Rozol or Fumarin.

↓

Continue monitoring for program evaluation

II. RAT BIOLOGY AND ECOLOGY

1. Species Described:

A. Norway rat - *Rattus norvegicus* Berkenhout

B. Roof rat - *Rattus rattus* L.

See pages 181-183, U.S. Department of Health, Education, and Welfare (1967) for a comparative key to rodent species.

2. Geographic Distribution:

See Howard & March (1974) for a detailed distributi map of rats of U.S.

A. Norway Rat - World-wide, including North America to southern Alaska and Hawaii. May be scarce in uninhabited areas of the Western U.S.

B. Roof Rat - World wide including coastal portions of California, Oregon, Washington, and most of the southern U.S. from Maryland to Texas.

3. Habitat:

A. Norway Rat - Closely associated with human habitation, may move to fields in warm months to feed on crops, but returns to buildings with advance of cold weather. May live independently of man in marshes. Outdoors, constructs burrows in ground; indoors, prefers lower floors, basements.

B. Roof Rat - Seems to be less dependent on man than Norway rats. May live in forests far from human habitation, especially in warm areas. See Pratt & Brown (1977) for detailed information on rat habitat. Arboreal outdoors; indoors prefer upper floors and attics.

NOTE: In areas of high population densities, Norway rats may live in trees and roof rats may burrow.

4. Hosts:

Pest rats generally live in close association with humans, feeding on stored or waste food and nesting in structures or outdoor urban areas.

5. Life Cycle:

A. Norway Rat - Breeds at any time during the year, but more frequently in warm months. Gestation lasts 22-24 days. Size of litter is usually 8-10 pups. A female may breed at 2-5 months of age and have an average of 3-4 litters per year. Adults weigh 10-17 oz. Life span generally 9-24 months.

B. Roof Rat - May breed throughout the year, but more commonly in warm months. Gestation lasts 20-22 days. Size of litter usually 4-8 pups. A female may breed at 2-5 months of age and have an average of 5.4 litters per year. Adults weigh 4-12 ounces. Lifespan is 9-12 months.

6. **Seasonal Abundance:**

Outdoor rat populations tend to peak in summer-early fall. They tend to be at their lowest levels in late winter-early spring, due to winter-associated mortalities. Indoors, rat populations may remain at the same levels throughout the year, limited only by shortage of food.

7. **Responses to Environmental Factors:**

Rat abundance is dependent on availability of food, water and shelter. When Norway and roof rats are found together, Norway rats will outcompete roof rats in most cases. Over-crowding may lead to increased aggressive behavior and lower birth rate in Norway rats. Increased emigration related to overcrowding is common in both species.

8. **Medical Importance:**

Rats have always been of medical importance due to their transmission of human diseases.

8.1 Direct Effects:

Rat bites, particularly in urban areas, may be a serious health problem. An estimated 14,000-24,000 bites to humans occur each year. Infants and helpless adults (unconscious, invalid, and elderly) are subject to attack by rats, sometimes fatally. All rat bites should receive medical attention.

Rats spread a number of human diseases directly through contamination of food and water with urine and feces.

8.2 Indirect Effects:

Rats may indirectly spread a number of human diseases by way of fleas and mites. Some of the more common diseases spread by rats include plague, rat-bite fever, Weils disease (leptospirosis), murine (scrub) typhus fever, ricketsialpox, trichinosis, salmonellosis, listerosis, toxoplasmosis, and lymphocytic choriomeningitis (see Pratt et al.(1976) for more complete treatment of rat-borne diseases).

8.3 Outbreaks of Rat Associated Diseases: Many of the diseases listed in Section 8.2 can be fatal to humans. If disease transmission is suspected in your area, contact your NPS Public Health Service representative, and collaborate with him on any measures needed to deal with outbreaks.

9. Natural Enemies:

A. Rats may be preyed upon by many other animals including dogs, cats, weasels, snakes and owls. Rats are susceptible to a variety of diseases and parasites. Some natural enemies ranging from ferrets to bacterial toxins have been used in the past with varying degrees of success in rat control programs.

B. In abnormally crowded conditions or other stress situations, rats may display aggressive behavior toward each other, including cannibalism and abandonment of young.

III. RAT MANAGEMENT

1. <u>Population Monitoring Techniques:</u>

A. Norway rat - Periodic surveys of buildings and grounds can reveal the existence of rat infestation. Although several techniques are effective for detecting rat presence (see below), a careful search for signs of rats should be conducted as well. Monitoring visits should be made every other week and increased or decreased according to the severity of the problem.

1. Signs of Rat Presence:

Sounds, droppings, burrows, urine stains, smudge marks, runs, tracks, gnawings, nests, food caches, pet excitement and rat odors are all signs of rat activity. Learn to differentiate between fresh rat sign and old sign which may indicate old (non-active) infestations (see Pratt & Brown (1977) for detailed descriptions).

a. Rat sign may be interpreted as follows:

<u>Rat free area or low rat population</u>:
no signs of rat presence; invaded only recently, or habitat will support few rats.

<u>Medium population</u>:
old droppings and gnawings common, one or more rats seen by flashlight at night, none during the day. Each rat seen at night usually indicates 10 or more elsewhere.

<u>High population</u>:
fresh droppings, tracks and gnawings evident, 4 or more rats seen at night or 1 or more in daylight.

b. Rat entry points (in structures) and travel routes (in structures and outside); see Howard & Marsh (1974). Adult rats can gain entrance through any opening larger than 3/4 inch square. Young rats (and adult mice) can gain entrance through openings as small as 1/2 inch square. Ill-fitting door jambs and window frames are common points of rat access.

Entry points, if frequently used, may have smudge marks from dirt and oil in the fur, or may be clean of dust. Travel routes are frequently found along walls due to rats' preference for keeping in contact with vertical surfaces (thigmotropism). Travel routes indoors are free from dust, and may have droppings and urine stains. (Rat urine will flouresce under ultraviolet light.) A 6" white band along the wall may be usefull in detecting rat presence in structures.

Travel routes outdoors can be detected by the lack of grass or presence of worn areas radiating to or from a single area.

2. Tracking powders, such as chalk or talc, may be used in likely runs in undisturbed indoor areas. A small amount is spread thinly on a area 6" x 18" and examined at regular intervals for tracks. Relative abundance of tracks is an indication of rat abundance.

3. Feeding rates - Estimates of the minimum number of rats present can be determined by placing premeasured, ground, nontoxic cereal bait in various locations to determined how much is eaten each night. Double the amount each night until the amount taken in one night levels off. Divide the amount by 1/2 oz. This will provide an estimate of the minimum number of rats (see Howard & March (1976) for detailed instructions).

4. Trapping - Estimates of numbers or approximate levels of infestation can sometimes be obtained by trapping. This method is not often used because remaining rats become trap shy and difficult to control. Trapping is normally used as a control measure.

5. Hole counts (outside) - Estimates of relative abundance can be made by counting, mapping, and loosely plugging burrow entrances on a weekly basis. Burrows which are open the following week are active. See Giraldi & Hackett (1982) for details.

B. Roof Rat - See 1.A. (Norway rat)

2. <u>Threshold/ Action Population Level:</u>

A. Norway Rat - In most circumstances the injury (threshold) level is one rat as determined by rat sighting or sign. The action level is one rat for population reduction programs and 0 rats for preventative programs.

B. Roof Rat - See 2.A. (Norway Rat)

3. <u>Management Alternatives - Non-chemical</u>:

A. Norway Rat

1. Habitat modification, i.e., reducing the capacity of the environment to support rats, is the most effective long term population reduction technique.

   a. Reducing food - In urban settings rats feed largely on garbage. Regular trash pickups at the end of each day, rather than storing trash overnight and the use of rat proof trash containers are relatively simple methods of reducing rat food sources. Food handling and food storage facilities should be made rodent proof (see below). Pet food dishes and water dishes should not be left full overnight. See Giraldi & Hackett (1982) for suggestions on rodent proofing trash containers and storage facilities (such as galvanized metal disks to prevent rats from gnawing into the bottoms of plastic trash containers).

   b. Reducing water - This technique is impractical in all but a few situations. If other water sources are unavailable, leaky faucets and seeps should be repaired.

   c. Reducing harborage - Outdoors: Landscaping should not include thick hedges or bushes which obscure the ground. Ground covers and walls should not include plants such as ivy which provide cover or runs for rats. Indoors: Buildings should be rat proofed with metal kick plates on doors, metal jambs on windows and doors, and cracks and holes in outside walls should be repaired. (see Scott & Borom (1976) for methods and techniques), L-shaped footers or curtain walls should installed where needed. Cement used in patching holes should be mixed with broken glass to prevent rats from digging it out before it sets and hardens.

2. Trapping - Trapping (along with baiting) is used where rapid population reduction is needed. Habitat modification should always accompany trapping or baiting to prevent future infestations. Traps are used in situations where use of poisons would be dangerous, to eliminate bait shy or bait resistant rats, to avoid odors from dead rats

in unaccessible places, or to collect live rats for ectoparasite or anticoagulant resistance screening. Snap traps are commonly used. Steel traps are considered dangerous and inhumane and should be avoided if possible. Glue boards are often used for mouse control, but can also be used against rats. (See CDC Publication #119 for information on trapping).

B. Roof Rat - See 3.A. Norway rat; in addition, all cables trees and pipes leading to or touching structures should be rat proofed with galvanized metal barriers to exclude this arboreal species if it is present. See Scott & Borom (1976), for details on indoor ratproofing. Giraldi and Hackett (1982) also give details on ratproofing in structures.

4. **Management Alternatives - Chemical**

A. Norway Rats - Rodenticides are commonly used to provide rapid reduction of rat populations. Rodenticides should be used in conjunction with habitat reduction to avoid chronic reinfestation.

1. Single dose (acute) rodenticides - These are fast acting poisons which kill rats after a single feeding. These chemicals should be applied by experienced professionals, as most are extremely hazardous. Examples of acute rodenticides include: red squill, strychnine, and ANTU.

Vacor and norbromide were once commonly used but are no longer registered for use in the United States.

2. Anticoagulants - These act only after the rat has consumed several doses. They act by disrupting the normal blood coagulation process, causing fatal hemorrhaging. They have the advantage over acute poisons in that they are safer to nontarget animals, and rats do not associate them with illness and learn to aviod them (as is the case with some single dose rodenticides). Some examples of anticoagulants include: warfarin, fumarin, difenacoum, tomorin, coumatetralyl, pical, diphacinone, chlorophacinone (Rozol®), and PMP. Broadifacoum (Talon®) is a second generation anticoagulant used as a single dose poison.

Resistance to some anticoagulants, especially to warfarin, has been noted in several U.S. cities.

3. Gassing - Several gasses are available for burrow and/or structure fumigation. Fumigants commonly used include: calcium cyanide, methyl bromide, carbon bisulfide, carbon dioxide, and phostoxin. These compounds are extremely hazardous and should only be used by experienced professionals.

B. Roof Rats - See 4.A.

5. Summary of Management Reccomendations:

1. Outdoors, reduce carrying capacity of habitat by reduction of cover (removal of thick shrubbery, rubbish piles, lumber stored on the ground, etc.)

2. Reduce availability of food by modifications to waste cans and dumpsters (repairing holes, use of galvanized metal plates to prevent rats from gnawing their way in, etc.). Do not store garbage overnight. Frequent pick-up and disposal will reduce rat food sources.

3. Indoors, repair all cracks and holes which may serve as entry points (rats can pass through any opening greater than 1/2" square). Structures should be rat proofed with galvanized metal shields over all entry points (door jambs, window frames, electrical wires leading to the structure, etc.). Branches touching the roof should be cut back. Use of L-shaped curtain walls will prevent rats from burrowing into structures.

4. If necessary, begin a trapping program in areas where humans or pets will not be injured. Use snap traps or glue boards if possible. Live traps may be used in special circumstances. Traps should be placed in areas of frequent rat usage (runways, where smudge marks appear, etc.).

5. If necessary, begin treatment with chlorophacinone (Rozol) or Fumarin in areas of known rat presence. Monitor frequently to make sure bait is accepted. Dispose of carcasses and uneaten baits.

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V. SAMPLE RAT MONITORING FORM

DATE:__________ PLACE:________________ INVESTIGATOR:____________________

OBSERVATIONS: (Note location if observed)
Droppings:
Smudge Marks:
Urine Stains:
Runs:
Gnawings:
Holes:
Tracks:
Nests and Food Caches:
Other:

STRUCTURAL DEFECTS: (Note location if observed)
Holes or cracks 1/2" or greater around pipes or wires:
Open vents or chutes:
Unscreened roof vents:
Wires (electrical or telephone) going to upper floors:
Other:

LANDSCAPE FLAWS: (Note location if observed)
Is heavy shrubbery or vine foliage providing possible cover? Y N
Is ground visible under shrubbery or flower beds to permit monitoring? Y N
Is lumber, fire wood, etc. stored on the ground? Y N
Other:

SANITATION:
How often is refuse collected?
Is refuse stored in the park buildings overnight?
Is material stored inside off the ground and away from walls?
Are refuse receptacles rodent proof?
Are there food concessions in the area?
Other:

Sketch in map or floor plan of area monitored. Show all items noted above.

Additional Notes:

NATIONAL PARK SERVICE
IPM Information Package

SCORPIONS & SPIDERS

Final Report

10 September 1984

Submitted To:

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

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

CONTENTS

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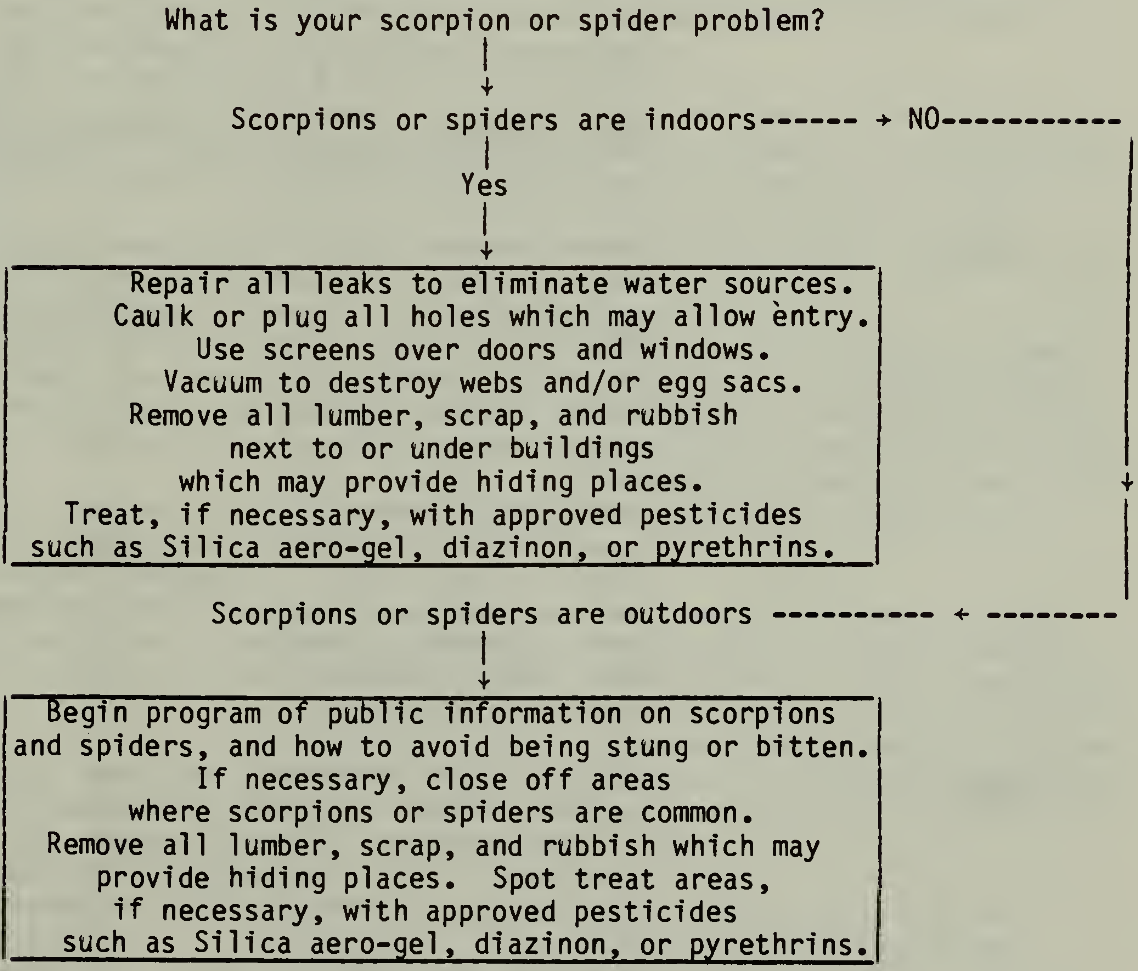
(Continued)

I. SCORPION/SPIDER IPM DECISION TREE

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



What is your scorpion or spider problem?

Scorpions or spiders are indoors

Repair all leaks to eliminate water sources.
Caulk or plug all holes which may allow entry.
Use screens over doors and windows.
Vacuum to destroy webs and/or egg sacs.
Remove all lumber, scrap, and rubbish next to or under buildings which may provide hiding places.
Treat, if necessary, with approved pesticides such as Silica aero-gel, diazinon, or pyrethrins.

Scorpions or spiders are outdoors

Begin program of public information on scorpions and spiders, and how to avoid being stung or bitten.
If necessary, close off areas where scorpions or spiders are common.
Remove all lumber, scrap, and rubbish which may provide hiding places. Spot treat areas, if necessary, with approved pesticides such as Silica aero-gel, diazinon, or pyrethrins.

II. BIOLOGY AND ECOLOGY OF SCORPIONS

1. *Species Described:* See pages 23-25 of U.S. Department of Health, Education, and Welfare (1967) for pictorial keys to common scorpions of the United States.

2. *Geographic Distribution:* In the United States, scorpions are most abundant in the Southwest in semi-arid to arid regions. Scorpions are considered rare north of a line traced from Baltimore, Maryland to St. Louis, Missouri; Salt Lake City, Utah; and San Francisco, California; but have been reported as far north as British Columbia (Ebeling, 1975).

   The sculptured scorpion (*Centuroides sculpturatus*) has been responsible for several deaths. It occurs mainly in Southern Arizona and parts of New Mexico, Mexico and California. Related but less venomous species occur in Big Bend National Park, Texas (*C. pantherienois*), and *C. chisosarius*). The striped scorpion (*C. vittatus*) ranges over the southern United States from South Carolina to New Mexico.

3. *Habitat:* Above ground scorpions (the genus *Centriuroides* which includes the deadly sculptured scorpion *C. sculpturatus*) are found in crevices in cliffs or in rock piles as well as under loose bark of trees and logs. Ground scorpions burrow in loose soil, gravel banks and sandy areas (including childrens' sand boxes). They emerge at night to hunt.

   In buildings, scorpions are commonly found in crawl spaces beneath buildings and in attics which they enter via wall voids. Scorpions require free water and are sometimes discovered in washrooms, kitchens, and bathrooms. Scorpions in buildings hide during the day in dark areas such as closets, in folded clothes, and shoes.

4. *Hosts:* Scorpions are predaceous on a wide variety of small animals including ground inhabiting insects, spiders, lizards and mice. Young scorpions feed avidly on termites. Prey is subdued by crushing with the chelae (pincers) or by rapid and repeated stings.

   Although they have 2-12 eyes, scorpions are nocturnal, and are thought to have poor vision; they can detect prey and enemies through minute vibrations detected through the chelae.

5. Life Cycles: Females typically produce living young which ride on the mother's back for 5-15 days. Young are born in early summer following spring mating. The young molt for the first time 3-6 days after birth. After the first or second molt, young leave the mother's back to fend for themselves. They reach sexual maturity in 3-5 years.Females produce 25-39 young, with the average at 32. Scorpions may live for several years depending on the species and availability of food and water.

6. Seasonal Abundance: Scorpion populations are relatively stable year round. They may become more abundant after the young have been born and have dispersed. Heavy rains may force scorpions to higher ground where they may become concentrated for short periods. Cold winters and cold, wet springs may reduce surviorship in the young.

7. Responses to Environmental Factors: Scorpions are nocturnal and avoid light. They require free water and spend most of the day hiding under objects or buried in sandy soil in order to conserve moisture. They can remain buried without food or water up to 6 months.

8. Medical Importance:

8.1. Direct Effect: Most species of scorpions inflict relatively mild stings (unless the victim is sensitive to venom). In most cases stings result in localized pain and swelling and occasionally black and blue areas near the sting site. (Envenomation should not be confused with anaphylactic shock which is a reaction to foreign protein.)

The sting from the sculptured scorpion does not cause swelling or discoloration. Typical sting symptoms include: extreme pain at the area of the sting, spreading numbness from the sting, weakness or paralysis of the injured area, hyperactivity and anxiety, profuse salivation, dizziness, difficulty in swallowing or speaking, respiratory distress or failure, and convulsions.

8.2. Indirect Effect: The major indirect effect of scorpions on people is the fear of being stung. This may lessen the enjoyment of the outdoors in areas where scorpions are common or have been sighted.

8.3. Preventive Measures & Treatment of Stings:

Information on avoiding scorpion stings should be posted. In essence, it consists of 3 common sense principles:

1. Do not put your hands or bare feet where you cannot see. Do not go barefoot at night.

2. Shake out clothes and shoes before putting them on.

3. If you feel something crawling on your body, do not swat, a quick brush instead will remove the creature before it can sting or bite. Swatting almost always guarantees reprisal.

If someone is stung, keep the victim quiet and reassured. Although there are no first aid measures of real value in the treatment of socrpion stings, ice should be placed over the wound to reduce pain and reduce swelling. The area should be immobilized. Keep exertion to a minimum and obtain medical assistance as soon as possible. Antivenin is not readily available in the U.S.; treatment is for symptoms.

9. Natural Enemies:

Scorpions are preyed upon by several animals including birds, mammals, certain spiders and other scorpions.

III. SCORPION MANAGEMENT

1. **Population Monitoring Techniques:**

Scorpions may be monitored by carefully inspecting areas where they hide during the day. Folded clothes, sandy areas, crawl spaces and attics should be checked. Areas where water is available such kitchens and bathrooms should also be inspected. Many species of scorpion floresce under UV (ultraviolet) light at night. Use of a UV light indoors or out may be helpful in locating active animals.

2. **Threshold/ Action Population Level:**

Indoors or in heavily used outdoor areas, one scorpion should be the level at which control measures are set. In areas where scorpions are common, visitors should be informed and instructed on how to aviod being stung and what to do if stung.

3. **Management Alternatives - Nonchemical:**

The elimination of harborage such as wood piles and trash near structures will reduce local populations. Free water such as drips or puddles should be repaired or eliminated and toilets treated with a thin film of petroleum jelly on the lip of the bowl to prevent scorpions from climbing in. All drains should be plugged when not in use or screened to prevent access from the outside. All cracks and possible entrance holes should be caulked or plugged to prevent access to the structure. Shrubbery should be pruned back from buildings.

4. **Management Alternatives - Chemical:**

The following pesticides are recommended for use in NPS areas against scorpions (Schwartz, 1982):

- Silica aero-gel
- Allethrin.
- Chlorpyrifos
- Diazinon
- Malathion
- Pyrethrins

Pesticides should be applied to cracks and crevices and around window and door casings.

Dusts are preferred for treatment because they can be blown into wall voids and attics. Residual pesticides may be desirable because scorpions may remain in a structure for a long time. Sprays may be effective when applied to hiding places.

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

5. Summary of Management Recommendations:

1. Repair all leaks and eliminate water sources
2. Remove trash and other hiding places from around structures.
3. Treat with approved pesticide if necessary.

IV. BIBLIOGRAPHY FOR SCORPIONS

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V. BIOLOGY AND ECOLOGY OF SPIDERS

1. <u>Species Described:</u>

See page 21-22 of U.S. Department of Health, Education, and Welfare (1967), for pictorial keys to common groups and Ebeling (1975), for detailed descriptions.

Although spiders are common throughout the United States, only two; the black widows (several species) and the brown recluse are dangerous to humans. Most other spiders are shy and highly secretive, are sluggish, or rare, or possess fangs which are too small or weak to bite through human skin.

Tarantulas, though large and menacing looking, are rather sluggish and only bite after extreme provocation. Bites are usually not serious, resulting in mild pain lasting up to 1/2 hour, with little or no swelling or inflamation.

Brown spiders related to the brown recluse (genus <u>Loxosceles</u>) have been known to bite but in most cases the results are not serious. An exception, the South American brown spider (<u>L. leata</u>), has been reported from California and Massachusetts. It is similar in appearance to the brown recluse and symtoms of its bite are similar (Ebeling, 1975).

A. Brown widow - <u>Latrodectus geometricus</u> Koch

B. Red widow - <u>L. bishopi</u> Kaston

C. Common black widow - <u>L. mactans</u> (Fab.)

D. Northern widow - <u>L. variolus</u> Walckenaer

E. Western widow - <u>L. hesperous</u> Chamberlin and Ivie

F. Brown recluse (violin spider) - <u>Loxosceles reclusa</u> Gertsch and Mulaik

2. <u>Geographic Distribution:</u>

Widow spiders of the genus <u>Latrodectus</u> are found in all states and southern Canada. They are frequently found in railroad cars and trucks and have spread worldwide.

A. Brown widow - South Florida.

B. Red widow - South Florida.

C. Common black widow - Southern United States to Southern New England.

D. Northern widow - Mid-Atlantic States to Canada (widely overlaps range of common black widow).

E. Western widow - United States and Canada west of the Rockies.

F. Brown recluse (violin spider) - Permanent range is Texas, Oklahoma, Kansas, Missouri, Illinois, Kentucky, Tennessee, Alabama, Louisiana, and Mississippi. Reported from New York, California, Pennsylvania, New Jersey, Florida, North Carolina, Wyoming, and Washington, D.C. but not believed to perisit outside of normal range (Snetsinger, 1982).

3. Habitat:

Black widow spiders commonly live outdoors under and among objects such as stones, pieces of wood, hollow stumps, rodent burrows, among the leaves of plants, or in low shrubbery.

Black widows are most frequently encountered by humans indoors in dry and sheltered locations such as privies, barns, poultry houses, garages and cellars. Woodpiles and trash heaps are also favored sites. Different species prefer different habitats; the brown widow seems to prefer structures while the northern widow prefers outdoor shelter in trash piles or under stones.

The brown recluse is found outdoors under objects or other sheltered places in its southern range. In northern portions of its range, it is found only indoors, it is found in undisturbed areas of any room, especially unused bedrooms, closets, cellars, and garages. It is often found hiding in unused clothes or old shoes.

4. Hosts:

All spiders are predators feeding upon insects and other arthropods. Spiders inject venom into their prey to subdue it, followed by injection of predigestive fluid to digest and liquefy the internal organs of the prey. Feeding is by ingesting the fluids. Spiders can go for some time without feeding; brown spiders (related to the brown recluse) have been kept for over 2 years without food. Black widows have survived over 3 months without food.

Spiders capture prey through a variety of methods, the most familiar of which is the web. Black widows and the brown recluse are web building spiders.

5. Life Cycles:

Black widows - Eggs are deposited in special silken sacs which are constructed by the female. The number of eggs per sac is usually 300-400 and a female may construct 4-9 sacs during a summer. The female guards the egg sacs and moves them if necessary to repair her web. Eggs hatch in 8-10 days and the spiderlings remain in the sac for 2-4 weeks after hatching. They molt once within the sac. Spiderlings remain near the sac for several days and then disperse by spinning silken threads and ballooning away on air currents. Spiderlings are heavily preyed upon by other spiders including other widows however females will not eat their own young. Spiderlings are protected somewhat by being toxic to vertebrates if eaten.

Spiderlings may pass through up to 9 instars but well fed individuals mature in as few as 4-7 instars over 2-6 months. Immature instars vary in appearance from other instars and from adults. Most widows overwinter as immature forms, maturing in May or June, and begin to die in large numbers by late July. Widows have been kept alive under laboratory conditions for up to 2 years.

The web of the black widow is an irregular mesh of threads in which the female hangs upside down. There is usually a small central pocket where the spider retreats when threatened. Webs are about one foot square. Widows living under stones outdoors may spin smaller webs or none at all.

Contrary to popular belief, the female does not normally devour the male after mating Males live longer when associated with females due to her sharing of prey captured in the female web.

Brown recluse - The female spins a white egg sac, convex above and flat beneath. Up to 40 spiderlings may emerge from a single egg sac and the female may construct 1-5 sacs in a summer. Only about half of the eggs produce spiderlings; the rest are infertile or eaten by the female or older spiderlings.

Brown recluse spiderlings pass through 8 instars to maturity. The time required to reach maturity may take 8-14 months depending on available food and ambient temperatures. Females may live up to 4 years, males slightly less.

In the southern United States, mating occurs from February to October with June to July the most active period. Egg sac construction and oviposition occurs from February to September. Adult females are relatively sedentary in their webs; males and young disperse widely.

The web of the brown recluse is an irregular maze of silk without a pattern. It is constructed in undisturbed areas, and is often not recognized.

6. Seasonal Abundance:

Most spiders, including widows and the brown recluse, are most common in spring and early summer when spiderlings emerge and disperse.

Spiders are most hungry and aggressive and therefore most likely to bite after they have constructed egg sacs and oviposited. Widows will attack any object that touches the web.

7. Response to Environmental Factors:

In warm regions, populations of spiders are fairly constant from one year to the next. In northern areas, sporadic outbreaks of widows occur, followed by years of comparative rarity. Overwintering populations are reduced by periods of warm weather followed by cold snaps in late winter and early spring.

Populations indoors in heated areas are regulated only by availability of food and living space.

8. Medical Importance:

All reported cases of spider bite should be referred promptly to a physician:

Black widows - Children, elderly persons and persons with chronic diseases such as heart or respiratory disease are most seriously affected by bites from widows.

Bites are generally not always felt but there usually is some slight swelling and redness, with 2 red spots which mark the penetration of fangs. Pain from the bite increases for up to 3 hours and gradually subsides in 12-48 hours. In severe cases, muscle rigidity and spasms may develop and the muscles in the abdomen may become extremely rigid. Nausea, fever, elevated blood pressure, and profuse perspiration are all common symptoms.

Brown recluse spiders - Brown recluse spiders prefer to flee if possible and will only bite after provocation. Most bites occur to individuals putting on old clothes or shoes which have not been worn for some time or by rolling on the spider in a long unused bed.

Typical symptoms of brown recluse spider bite include a stinging sensation followed by intense pain. Pain may occur immediately after the bite or up to several hours. A small blister forms at the bite, surrounded by sore tissue. The tissue killed by the venom sloughs off sometimes exposing underlying muscle tissue. Healing may take 6-8 weeks resulting in a sunken scar ranging in size from a penny to a half dollar depending on the amount of venom injected, and the sensitivity of the victim. Secondary infection frequently occurs during the healing process. The bite is rarely fatal. Treatment should begin within 48 hours of the bite to have any effect.

9. **Natural Enemies:** Spiders are preyed on by a great variety of animals including insects, reptiles, birds, and some mammals, as well as scorpions and other spiders.

Black widows are preyed on by a related species (*Steatoda grossa*) which may occur indoors, by pirate spiders (*Mimetus sp.*), and by the blue burglar wasp (*Chalylion californicum*), which provisions its nest exclusively with widows as food for developing larvae. Eggs are preyed on by a fly (*Pseudogaurax signatus*) and parasitized by several parasitic wasps.

Little is known about the predators and parasites of the brown recluse, but cannabalism is common among young and adults.

VI. SPIDER MANAGEMENT

1. **Population Monitoring Techniques:**

Spiders are best monitored by visual search.

Webs are commonly constructed indoors in undisturbed places such as crawl spaces, cellars, and other sheltered, dry locations. Old unused webs are dusty and torn. Webs with fresh egg sacs are occupied.

2. **Threshold/ Action Population Level:**

Most species of spiders are considered beneficial in that they consume large quantities of insects. Tolerance levels for these spiders may be quite high in most park situations.

Widows and the brown recluse, due to their potentially dangerous bites, should not be tolerated in areas where they may encounter humans. The threshold level for these species is one spider or active web.

3. **Management Alternatives - Nonchemical:**

Spiders feed almost exclusively on invertebrates. Measure taken to reduce insect populations will also reduce the number of spiders preying on them. Tightly fitting screens on doors and windows will exclude adult spiders (newly hatched spiderlings can pass between screen mesh). Firewood, plants, and other objects brought into structures should be inspected first. All rubble, scrap, and lumber should be removed from buildings and away from exterior walls. Webs and egg cases can be destroyed by vacuuming and discarding or burning the bag.

In areas where widows or the brown recluse are common, follow the same precautions that would normally help prevent against scorpion stings.

4. **Management Alternatives - Chemical:**

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

Silica aerogels
Chlorpyrifos
Diazinon
Malathion
Pyrethrins
Resmethrin

Indoors, a crack and crecice treatment is best.

Outdoors, dusts penetrate into wood or rubble piles where spiders spend such of their time. Silica aerogels may be used to treat attics, crawl spaces or wall voids.

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

5. <u>Summary of Management Recommendations:</u>

1. Exclude spiders by use of screens and repair any holes which may allow entry.
2. Practice good sanitation by removing all rubble, scrap, and lumber piles from in and around buildings.
3. Vacuum to destroy webs and egg sacs.
4. Treat webs, cracks, crevices, and other areas with approved pesticides after the above actions have been carried out.

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NATIONAL PARK SERVICE
IPM Information Package

TENT CATERPILLARS

Final Report

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Submitted To:

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Washington, D.C.

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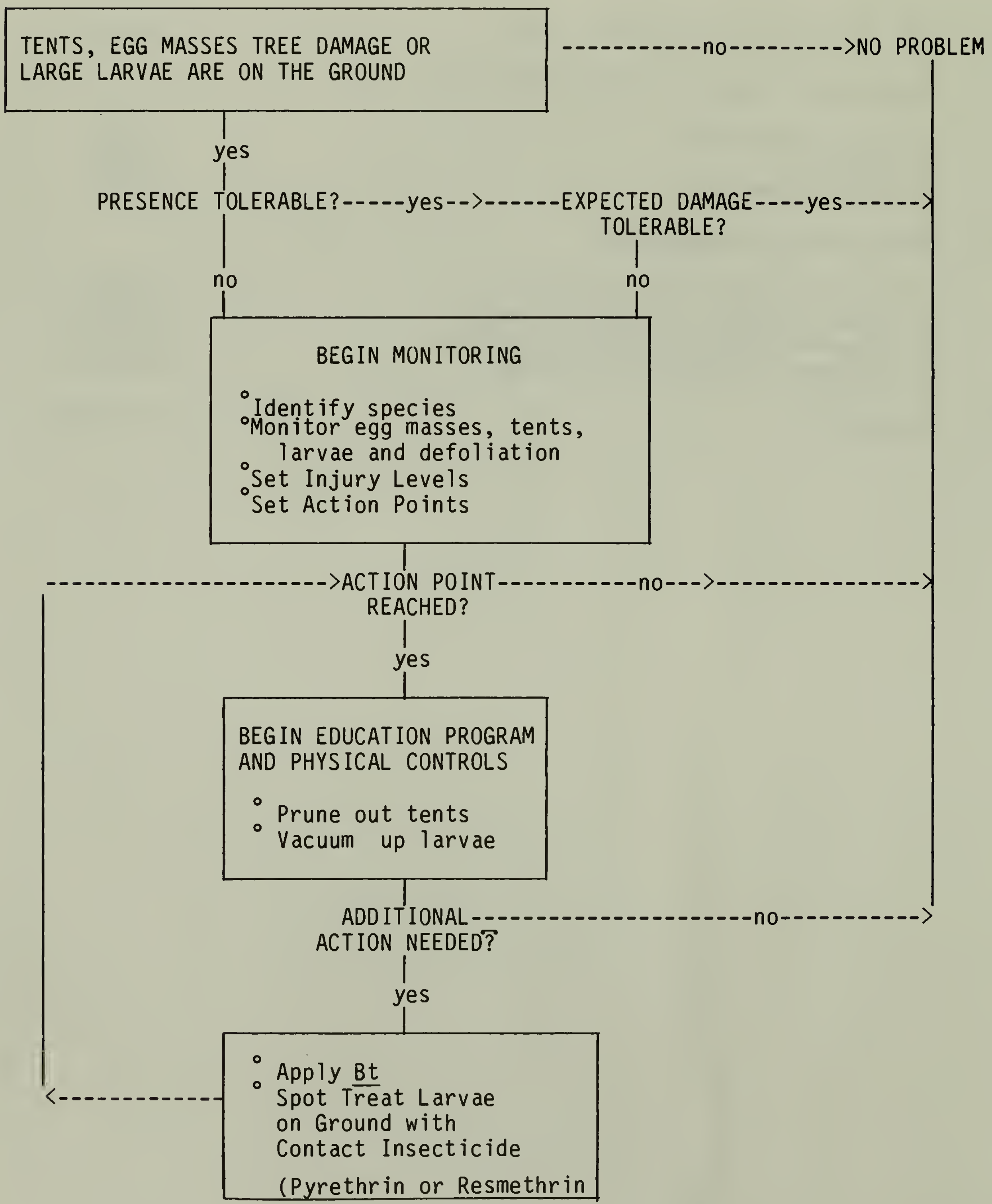
CONTENTS

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

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* 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 ($\overline{x} = 21.2$). Two observers using binoculars each underestimated the number of egg masses by 145 and 131 (about 65%). The masses are about the color of twigs and are easily confused with bud scars. Egg mass counts could be useful with other *Malacosoma* species, especially where trees are small.

Connola et al. (1957) also tested the binocular method and obtained approxi-mately the same results. However, they compared egg mass counts by sampling 10 twigs and by counting egg masses from cut trees. They found that twig samples cut with pole pruners detected about ¼ of the total egg mass count. These workers elaborated the use of egg mass collection data further showing how the number of egg masses could be used to estimate defoliation. They also indicate that cut-twig samples is a highly efficient sampling system.

Frass collections made by placing funnels, cloth traps, or sticky paper beneath the crown of infested trees has been used to determine the species, stage of development and relative density of larval populations. Hodson (1941) cites earlier workers who used this technique in field applications, but his own work was conducted with laboratory colonies. He indicated the weight, length and width of frass samples which correspond to the different instars. This technique can be used in field sites to show when the early instars begin feeding as they are particularly difficult to detect. The frass technique is subject to error when other frass-producing species are present and can be confused with the primary insect.

With tent making Malacosoma species the tents appear with the onset of larval feeding and thus provide a visual method for estimating potential damage. With such species frass collections would be useful only for the short period between larval hatch and the point when the tent can be detected visually. However, frass collections will be subject to some degree of error as some frass accumulates in the tent and is difficult to measure or estimate.

The cocoon sampling methods Hodson evaluated were: timed collections, temporary sample quadrats, permanent sample quadrats, general collecting and tree collections. Timed collections, where cocoons were hand picked for a definite length of time (usually three minutes), compared favorably with square meter quadrant counts, although they were recognized as not representative for very low and very high populations.

By calculating the number of larvae (from the number of masses per tree, the number of eggs per mass, and the percentage survival), the number of leaves they are known to eat per tree, and the estimated total foliage on the tree, a "defoliation ratio" can be obtained. This ratio (the number of leaves to be eaten divided by the estimated number of leaves on a tree) gives a measure for predicting the extent of defoliation. Ratios greater than 1:1 predict complete defoliation. This information has been simplified to a table (see Table 3) where D.B.H. (diameter at breast height) of the target tree and number of egg masses would be indicative of complete defoliation. However, Hodson indicates that in certain situations this method did not function to predict expected catastrophic population numbers.

The best means of determining injury levels and action points is to monitor egg masses in the fall to gain an estimate of how large the early larvae populations will be in the spring. Sampling again in the spring is needed to correlate fall egg mass levels with spring larvae populations (e.g. how many larvae actually hatch out of the eggs). If populations are high, frequency of monitoring should be adjusted to insure that decisions regarding treatments can be made before unacceptable damage ocurs. Weekly monitoring may be warranted during spring hatch if populations appear high. Less frequent monitoring (e.g. bi-weekly or monthly), may be sufficient with lower populations.

Table 3.

THE NUMBER OF EGG MASSES CAUSING COMPLETE DEFOLIATION IN RELATION TO TREE DIAMETER IN NORTHERN MINNESOTA ON ASPEN, *POPULUS TREMULOIDES*, BY THE FOREST TENT CATERPILLAR, *MALACOSOMA DISSTRIA**

DIAMETER AT BREAST HEIGHT (inches)	(centimeters)	NUMBER OF EGG MASSES DETECTED **
1	2.5	2
2	5.0	5
3	7.5	9
4	10.0	11
5	12.5	14
6	15.0	19

* From Hodson 1941.

** The number of trees felled to collect these masses was not indicated.

As tents or aggregates form staff should be able to determine how many "tents" per tree can be tolerated without exceeding the aesthetic injury level. When the fall and spring monitoring program indicates that the number of tolerable tents will be exceeded, treatments can be implemented. If the pest species is the forest tent caterpillar which does not form tents, the number of spring larval aggregates rather than the number of tents will have to be counted.

In northern Minnesota during the early years of a large forest tent caterpillar outbreak lasting five years Hodson (1941) indicates hatching occurred on May 12, 1936 and May 10, 1937. The first overwintering egg masses were discovered on July 29, in 1937. In other areas and with other species the spring hatch will occur about the time of bud break and leafing out.

In conjunction with the egg mass numbers, the number of tents per tree, cocoon numbers, frass collections, or defoliation ratios, etc., natural enemy populations also need to be measured in order to be able to predict outbreaks. The most important measurements of natural enemy populations are of the larval and pupal parasites, *Rogas sp*. and *S. aldricki*. *Rogas* can be sampled by collecting larval specimens and rearing them temporarily until pupation or until a "mummy" (or parasitized specimen) is formed. Larval dissections also can be performed but considerable skill is required in order to distinguish the local parasite and hyperparasite larval forms with precision.

Larvae reared to the pupal stage and collected pupae can be held in small vials with cotton stoppers until parasites emerge. Percentages of the different representative larval or pupal collections can be calculated from dissections and/or emergence data. Total percentages of all primary parasites and hyperparasites should be added since hyperparasites emerge from primary parasites. The impact of parasites on the pestiferous larval herbivore population is assessed by summing all percentages for particular larval collections and plotting trends in comparison with similar trends of larval tent caterpillar densities. More elaborate statistical procedures for assessing natural enemy impacts are discussed in van den Bosch et al. (1982).

2. Threshold/ Action Population Level:

Injury level refers to the point in the growth of the pest population when the numbers of pest organisms are sufficient to cause some unacceptable kind or degree of structural, economic, aesthetic or medical damage (injury). Where the damage is primarily an aesthetic one it may be useful to substitute the phrase "tolerance" levels as a synonym for "injury" levels. In other words, one needs to determine how much change from the "ideal" appearance can be tolerated before treatment actions against the target pest are required.

Several questions should be considered in establishing an injury/tolerance level. These include:

a. will defoliated trees die?
b. will defoliated trees cause unacceptable aesthetic injury?
c. what number of tents or larval aggregates per tree will cause unacceptable aesthetic injury?

In natural areas tent caterpillar outbreaks should be regarded as part of the natural ecosystem. Defoliated trees are seldom killed. However, if trees are under other stresses (e.g. drought, disease) repeated defoliations may result in death of some trees. However, it may be appropriate to tolerate even relatively large scale tree mortality in a natural area since such an occurrence is part of the natural dynamics of the forest.

In developed areas where visitor use is high, large numbers of tents, larvae or egg masses may warrant treatment even though no permanent damage to the vegetation is likely to occur. This is due to the short-term "aesthetic" damage to ornamental plants which may result from high populations of caterpillars, or the obvious presence of large numbers of larvae seeking pupation sites after finishing their feeding period.

Visitors will require interpretive services during tent caterpillar outbreaks either to reduce their fears or to satisfy their curiosity. These educational services can impact attitudes and consequently the tolerance for various populations of the pest.

In the short term, one way to determine injury level guidelines particularly for "aesthetic injury" during tent caterpillar outbreaks might be to determine the costs in staff time to educate the public on the reasons no treatment is occuring compared to the costs (labor, materials, potential political and financial liability) of applying treatments.

The action point is that point in time when pest suppression must take place to prevent the injury level from being reached (or the tolerance level from being exceeded).

There are three periods when actions should be taken:

a. in the fall or winter against the egg masses
b. in the spring after all eggs have emerged
c. during large outbreaks when large larvae move from defoliated trees and wander in search of pupation sites

During the fall and winter, treatments can occur anytime after all the eggs have been laid and leaves have fallen so that masses are visible. Timing is critical for early spring treatment of the larvae as the insecticide of choice is Bacillus thuringiensis (Bt), a stomach poison, and the larvae have to actively ingest a lethal dose. The spring action point will occur after all masses have hatched but before larvae have ceased feeding prior to pupation. Projected impact of natural enemies based on information obtained from monitoring should be factored into decisions to treat.

3. Management Alternatives-Nonchemical:

Indirect suppression strategies and tactics are those that change the conditions that create or define the pest problem. Examples are:

a. design or redesign of the landscape, structure or maintenance for the purpose of reducing or eliminating the pest problem;

b. modifying the habitat in some major way to discourage the pest species;

c. human behavior changes including the alteration of use patterns or maintenance practices contributing to the pest problem, or education to increase tolerance levels for the "pest" species or the aesthetic damage it causes.

In developed areas where tent caterpillars are a chronic pest problem the landscape design process should specify plant species which are not susceptable to this pest group. Similarly, existing landscapes which are not historically important nor part of the natural setting also can be redesigned to minimize available habitat for tent caterpillars.

For example plant species with extrafloral nectaries that attract ants such as Formica obscuripes which prey on tent caterpillars (Tilman, 1978) could be added to the landscape Where unacceptable pest numbers repeatedly occur, the habitat surrounding the seasonally-infested plants could be screened from view by additional plantings.

There are a number of case histories where habitat alterations improved survival or increased the reproductive potential of natural enemy populations and reduced pest populations. A short review of this subject is provided by Rabb et al. (1976). Installing nest boxes to increase insectivorous bird populations and predacious wasps (i.e. Polistes spp.) have been used in some settings to increase predation rates against other caterpillar species. Beyer and Moore (1980) remark on the predatory effects of various cuckoos on tent caterpillars and Jackson (1979) points out that in order to allow a build-up of these voracious caterpillar predators there must be at least patches of thicket in the understory as this habitat is where they select nest sites. Leius (1967) shows that orchards rich in wild flowers had 18 times as many parasitized eastern tent caterpillar pupae as those orchards with poor wildflower undergrowth.

During normal pruning activities efforts should be made to remove egg masses if a pest problem is anticipated.

In periods when large outbreaks are occurring efforts to educate visitors and staff about the biology and ecology of the tent caterpillar species in question can increase tolerance levels and reduce public pressure for treatments. Similarly, if treatments take place, educational efforts should be directed to describing why the decision to treat was made and the nature of the treatments selected.

In small areas where an aesthetic problem occurs pruning out tents or scraping egg masses may provide temporary local suppression. On highly prized ornamentals (e.g. Japanese cherry trees at Hains Point in the National Capital Region of the NPS) spot pruning with a pole pruner was sufficient as a management technique when a small number of tents were present. The use of a portable vacuum for removing large larvae which have finished feeding and have begun wandering can be useful where they are causing intolerable aesthetic damage.

Two deliberate biological control approaches are useful in managing tent caterpillar problems: conservation and augmentation of natural enemy populations. The conservation of existing natural enemy populations by minimizing damage from human activities, e.g. treatments with non-selective agents, habitat destruction, etc. is an essential part of maintaining existing natural enemy complexes. Some methods for augmenting natural enemy populations have been discussed under the Design or Redesign section. The use of the microbial control agent, Bacillus thuringiensis (Bt) is considered an aumentative biological control tactic because the microbe occurs naturally and universally as an insect pathogen but is augmented by periodic releases when increased populations will reduce an insect pest population.

In large population outbreaks applications of the selective microbial insecticide Bt is the material of choice since it alone among the materials available for treatment of tent caterpillars does not damage the natural enemy populations. Natural enemy populations are responsible for ending most caterpillar outbreaks. If they are damaged by treatments, outbreaks may continue for additional seasons. Among the materials commonly recommended in attempts to suppress tent caterpillar populations are: acephate, carbaryl, diazinon, dimilin, malathion, methoxychlor, and trichlorfon (see Hamel, 1981, Retnakaran et al. 1979). All these materials can cause mortality to natural enemies of tent caterpillars. Using mixtures of these or related materials with Bt defeats the purpose of using a selective agent like Bt since it incorporates an unselective component.

Bt currently is sold under the trade names: Thuricide® (Sandoz), Biotrol®, Dipel® (Abbott Laboratories), and Bactospeine® (Biochem). For a current research update on Bt consult Burges (1981). A comprehensive review article including history, mechanisms, taxonomy and use of Bt was prepared by Dubois and Lewis (1980).

Bt is a bacterial stomach poison and must be eaten to become toxic. The rod-shaped spore-forming gram positive bacterium produces a diamond-shaped protein crystal referred to as the delta-endotoxin. The spore stage and the protein crystal are contained within the same cell. When released from the cell and dissolved the crystal is toxic to many insects. The crystal is composed of aggregates of proteins which after ingestion by certain insects with highly alkaline (pH of 9+) guts and the appropriate enzymes, dissolves into toxic components. These toxic components (or endotoxins) block the enzyme systems that protect the caterpillar's gut from its own digestive juices. Within 10-15 minutes holes appear in the gut wall and the insect usually stops feeding. Bacterial spores then invade the insect's body cavity through these holes and produce a septicemia which kills the insect.

4. Management Alternatives-Chemical:

Table 4 compares commonly recomended chemical controls and the microbial control Bt. Bt effectively kills tent caterpillar populations selectively, is harmless to humans and degrades completely to non-toxic components. From a pest control viewpoint alone, the use of Bt against actively feeding larval stages rather than another material is superior because it does not directly damage the natural enemy populations. However where a large larval population is wandering on the ground, in or on buildings, or on roads or pathways, and where vacuuming alone will not remove them a short-lived contact insecticide may be useful. The material of choice in such a situation is a pyrethrum extract (frequently called pyrethrins as the extract is a mixture of active materials), or a synthetic pyrethroid with a high LD_{50}.

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

Table 4.

A COMPARISON OF EFFICACY, SELECTIVITY, TOXICITY, AND FATE OF INSECTICIDES USED AGAINST TENT CATERPILLARS*

INSECTICIDE	EFFICACY**	SELECTIVITY	TOXICITY (LD_{50})	MOBILITY¶	COMMENTS
Acephate	H	L	M	M	
Bacillus thuringiensis	H	H	0	0	
Carbaryl	H	L	M	M	
Diazinon	H	L	M	M	
Malathion	H	L	L	M	mobility is an estimate
Methoxychlor	H	L	H	H	
Pyrethrins	H	L	L	L	
Trichlorfon	ND	L	M	M	mobility is an estimate

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* 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

TICKS

Final Report

27 July 1984

Submitted To:

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

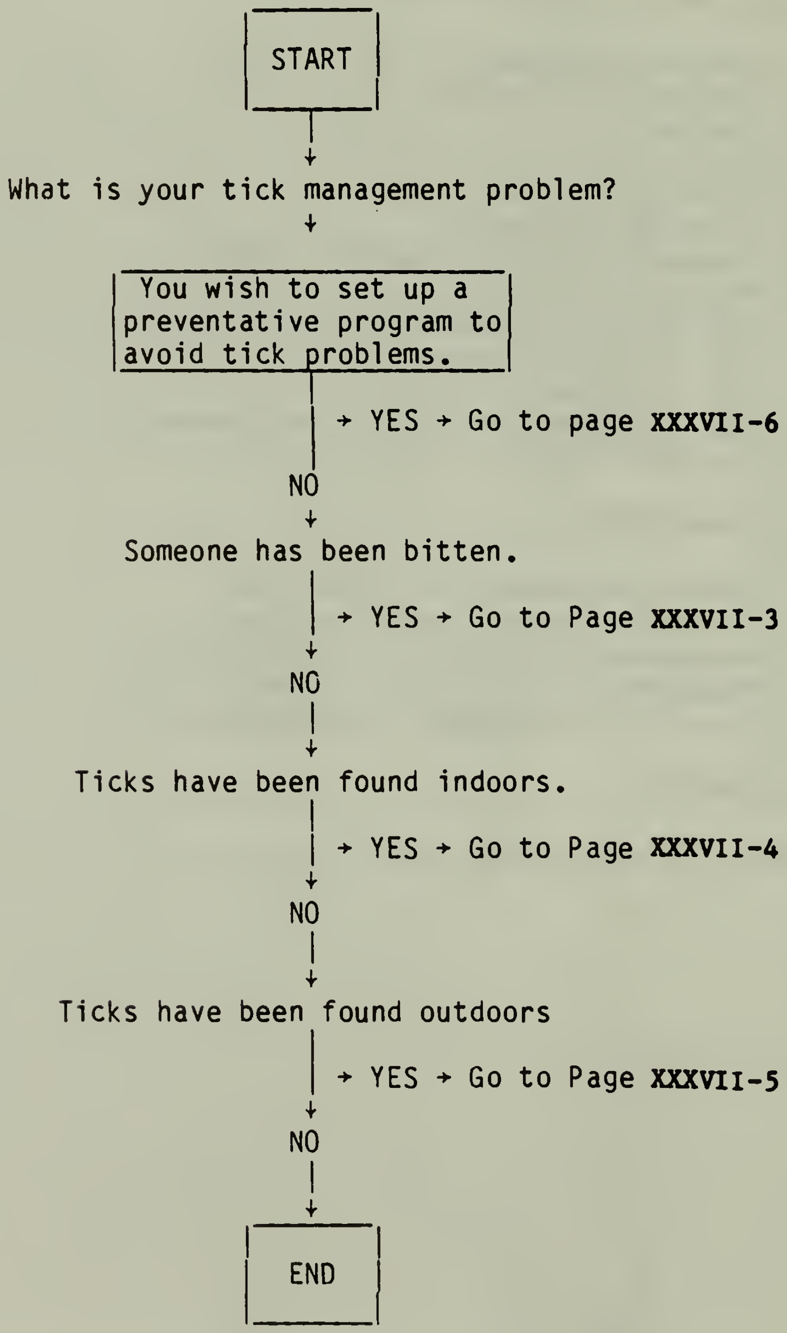
Submitted By:

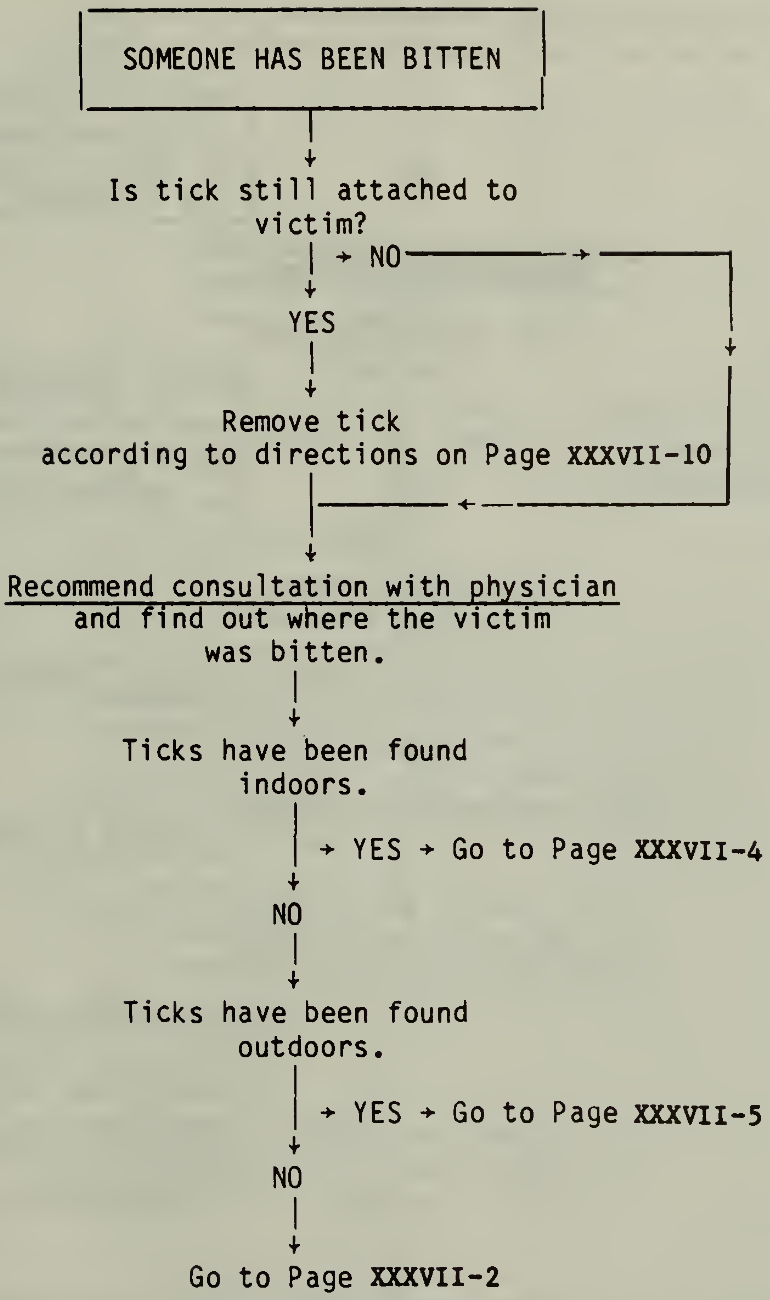
Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

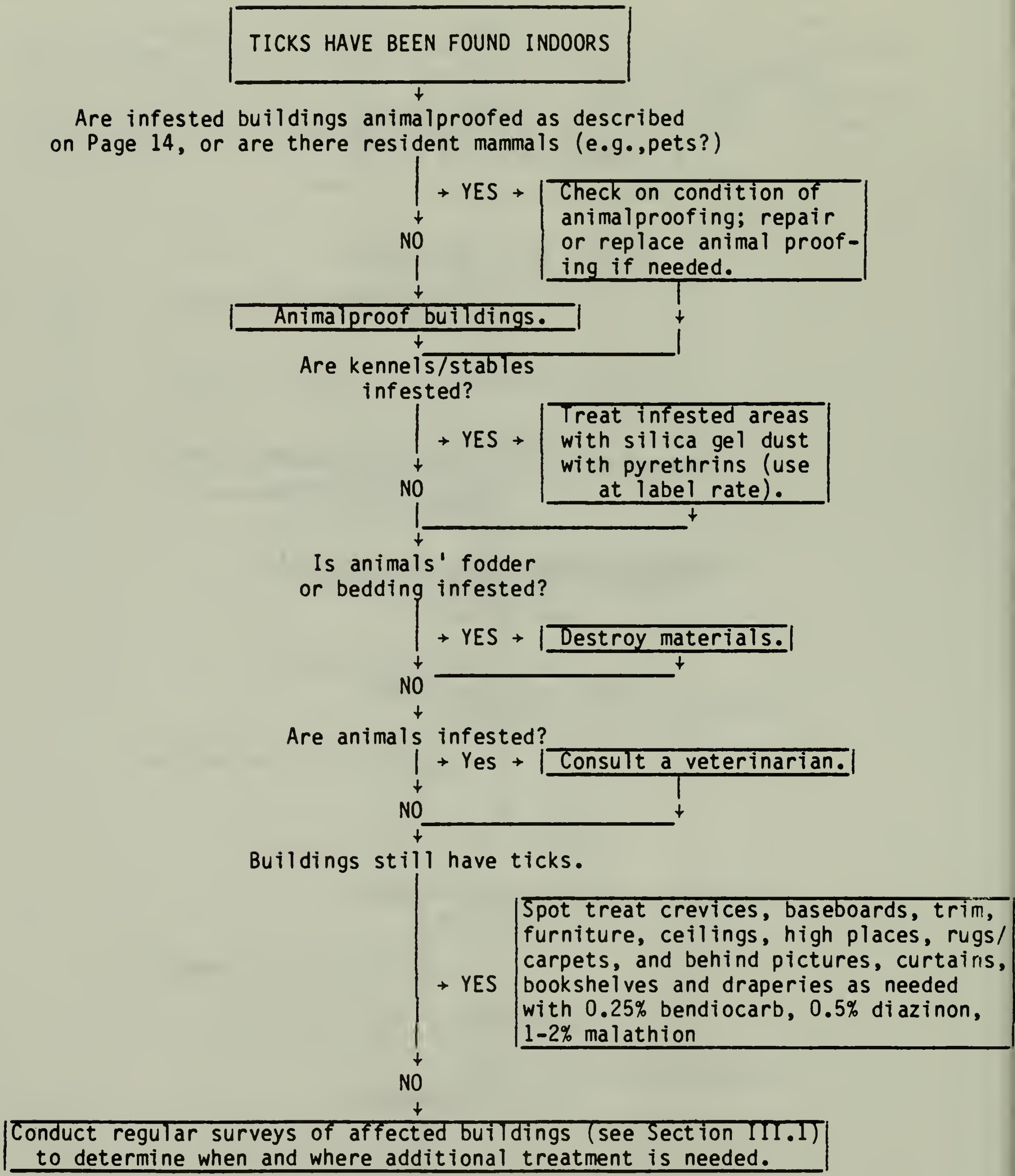
CONTENTS

I. TICK IPM DECISION TREE

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




SOMEONE HAS BEEN BITTEN
Is tick still attached to victim?
NO
YES
Remove tick according to directions on Page XXXVII-10
Recommend consultation with physician and find out where the victim was bitten.
Ticks have been found indoors.
YES
Go to Page XXXVII-4
NO
Ticks have been found outdoors.
YES
Go to Page XXXVII-5
NO
Go to Page XXXVII-2



TICKS HAVE BEEN FOUND INDOORS

Are infested buildings animalproofed as described on Page 14, or are there resident mammals (e.g.,pets?)

YES → Check on condition of animalproofing; repair or replace animal proofing if needed.

NO → Animalproof buildings.

Are kennels/stables infested?

YES → Treat infested areas with silica gel dust with pyrethrins (use at label rate).

NO

Is animals' fodder or bedding infested?

YES → Destroy materials.

NO

Are animals infested?

Yes → Consult a veterinarian.

NO

Buildings still have ticks.

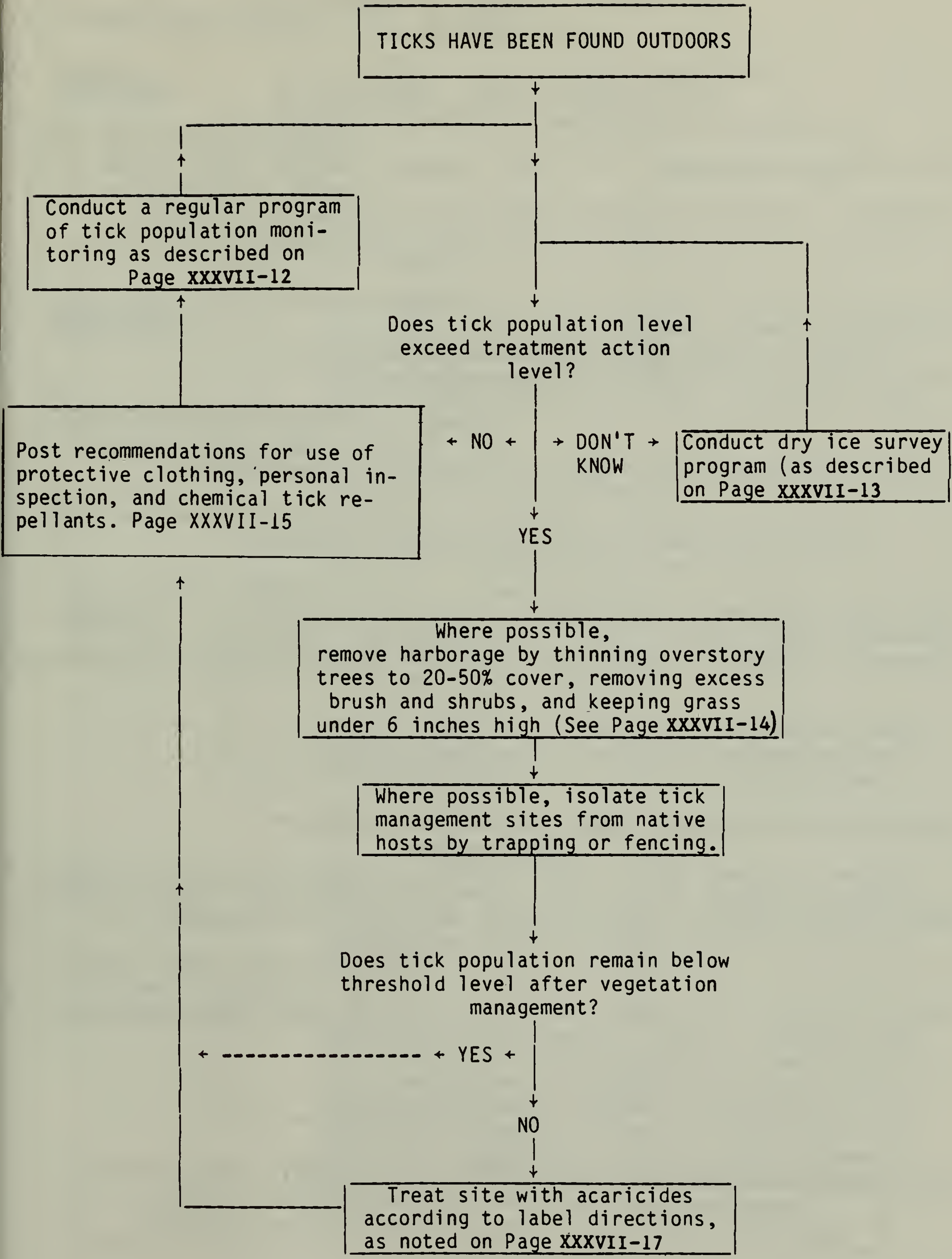
YES → Spot treat crevices, baseboards, trim, furniture, ceilings, high places, rugs/carpets, and behind pictures, curtains, bookshelves and draperies as needed with 0.25% bendiocarb, 0.5% diazinon, 1-2% malathion

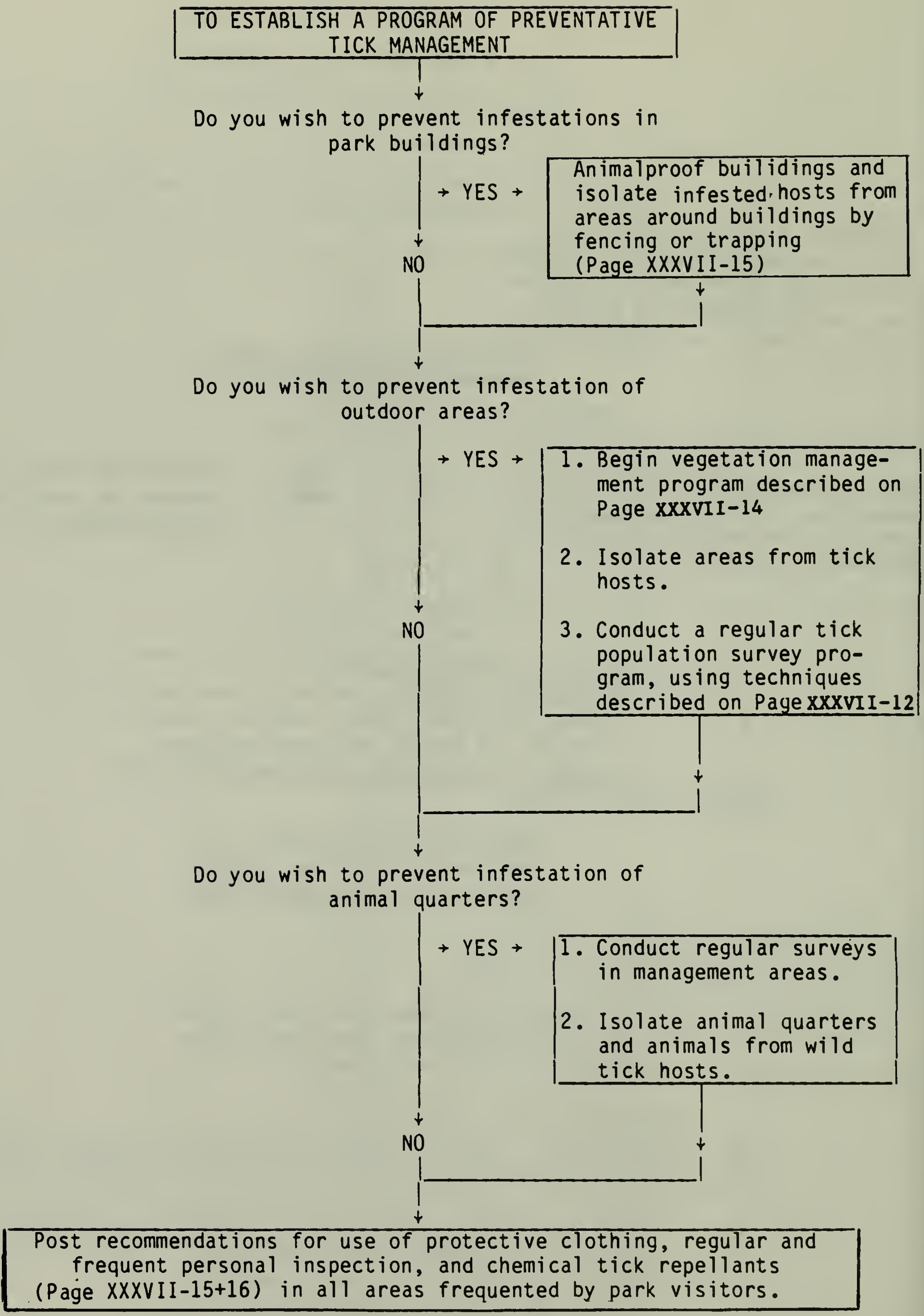
NO

Conduct regular surveys of affected buildings (see Section III.1) to determine when and where additional treatment is needed.

*From A. Mallis, ed. Handbook of Pest Control, 2nd. Ed. 1982.

**Bendiocarb is registered for use by certified applicators only.


TICKS HAVE BEEN FOUND OUTDOORS
Conduct a regular program of tick population monitoring as described on Page XXXVII-12
Does tick population level exceed treatment action level?
NO
DON'T KNOW
Conduct dry ice survey program (as described on Page XXXVII-13
Post recommendations for use of protective clothing, personal inspection, and chemical tick repellants. Page XXXVII-15
YES
Where possible, remove harborage by thinning overstory trees to 20-50% cover, removing excess brush and shrubs, and keeping grass under 6 inches high (See Page XXXVII-14)
Where possible, isolate tick management sites from native hosts by trapping or fencing.
Does tick population remain below threshold level after vegetation management?
YES
NO
Treat site with acaricides according to label directions, as noted on Page XXXVII-17



TO ESTABLISH A PROGRAM OF PREVENTATIVE TICK MANAGEMENT

Do you wish to prevent infestations in park buildings?

→ YES → Animalproof builidings and isolate infested hosts from areas around buildings by fencing or trapping (Page XXXVII-15)

NO

Do you wish to prevent infestation of outdoor areas?

→ YES →

1. Begin vegetation management program described on Page XXXVII-14
2. Isolate areas from tick hosts.
3. Conduct a regular tick population survey program, using techniques described on Page XXXVII-12

NO

Do you wish to prevent infestation of animal quarters?

→ YES →

1. Conduct regular surveys in management areas.
2. Isolate animal quarters and animals from wild tick hosts.

NO

Post recommendations for use of protective clothing, regular and frequent personal inspection, and chemical tick repellants (Page XXXVII-15+16) in all areas frequented by park visitors.

II. BIOLOGY AND ECOLOGY OF TICKS

1. **Species Described:**

A. Lone Star Tick - *Amblyomma americanum L*.

B. American Dog Tick - *Dermacentor variabilis* Say

C. Rocky Mountain Wood Tick - *Dermacentor andersoni* Stiles.

See U.S. Department of Health, Education, and Welfare (1967), page 40, for a comparative key to important tick species.

2. **Geographic Distribution:**

A. Lone Star Tick - Texas, Oklahoma, Misouri, Arkansas, Louisiana, Mississippi, Alabama, Tennessee, Kentucky, Illinois, Indiana, Ohio, West Virginia, Virginia, Maryland, Delaware, New Jersey, South Carolina, North Carolina, Georgia, Florida. May also occur in New England States.

B. American Dog Tick - East of Rocky Mountains, and in California, Oregon, Indiana, and West Virginia.

C. Rocky Mountain Wood Tick - Widely distributed throughout the United States and Canada.

3. **Habitat:**

A. Lone Star Tick - Wooded areas, especially where there is dense underbrush. Also found in scrub, meadow-margins, hedge rows, cane breaks, and marginal vegetation along rivers and streams.

B. American Dog Tick - Wooded areas, abandoned fields, medium-height grasses and shrubs between wetlands and woods, and sunny or open areas around woods.

C. Rocky Mountain Wood Tick - Fields and forested areas.

4. **Hosts:**

Ticks are blood feeders on many species of mammals including humans. While adults generally feed on large hosts, larvae and nymphs are more likely to feed on small hosts. The Lone Star Tick also feeds on many birds.

5. **Life Cycle:**

A. Lone Star Tick - Eggs are deposited in middle to late spring under leaf and soil litter. Incubation may take 30 days or longer, depending on the temperature. Newly hatched larvae feed within five days after hatching, and remain attached to their host for 3-7 days. After feeding, larvae fall from their hosts, and hide in vegetation. Molting occurs between 9 and 27 days after feeding. Newly molted nymphs attach to a second host within 9-27 days. Nymphal feeding may last 38 days, and is followed by a 13-46 day resting period before the second molt. Newly molted adults attach to a third host after 3-10 days, and feed for 6-24 days. Oviposition occurs 7-16 days after the last blood meal; a single female may produce 8,000-10,000 eggs over 9-28 days. Males die after mating (after the final blood meal). The complete life cycle requires about 2 years.

B. American Dog Tick - Over 14 to 32 days, the female lays masses of 4,000 to 6,500 ellipsoidal, yellowish-brown eggs, and then dies. The eggs normally hatch in 36 to 57 days. The unfed larvae crawl about, seeking hosts, and can live for more than a year (540 days maximum) without food. In a simulated meadow, larvae became engorged on mice in an average of 4.4 days, then dropped from their hosts seeking protected places to molt. The nymphs crawled about seeking hosts. The engorging period ranged from 3 to 11 days; the greatest number dropped on the sixth day, and found protected places in which to molt. They molted after 3 weeks to several months. Nymphs also could live for more than a year without food; the maximum period was 584 days (Metcalfe and Flint, 1962).

Unengorged adults may live for more than 2 years if they do not attack to animals. The engorgement of females requires 5 to 13 days, and mating takes place on the host. In the absence of suitable hosts, the life cycle of the American dog tick may last 4 or more years. Under favorable conditions, the life cycle may last only 3 months.

C. Rocky Mountain Wood Tick - Females lay eggs in plant debris on the soil or in crevices in construction materials, usually in masses of hundreds at a single location. Eggs hatch into six-legged larvae ("seed ticks") that attach themselves to host animals and feed on blood. After the blood meal, the larvae generally drop to the ground to molt and become eight-legged nymphs. Nymphs take another blood meal (from different host species), and develop into mature adults. Wandering males frequently mate with feeding females. Mated females take another blood meal before producing eggs. Ticks characteristically become greatly enlarged on feeding (engorgement).

If the larva, nymph, or adult does not find a suitable host, it survives for extended periods without feeding (or molting). A single life cycle may last 3 years or more.

6. Seasonal Abundance:

A. Lone Star Ticks - Abundance of lone star ticks in Oklahoma has been documented by Hair and Howell (1968):

-larvae are most active from mid-June through mid-November,

-nymphs are active from mid-March through mid-October, and

-adults are active from mid-March through August, and may appear from December to mid-February.

B. American Dog Tick -Newhouse (1983) found adult ticks active in Georgia forests from March to September. Population peaks occurred during the first and last weeks of May, and the last week of June. Adults are most active in New York from mid-April to mid-July.

C. Rocky Mountain Wood Tick - Adults and nymphs can be found from late March to late summer, and feed from mid-March to mid-July. No additional information was available.

7. Responses to Environmental Factors:

A. Lone Star Tick - Tick abundance is dependent on high relative humidity, high soil moisture, and low daytime temperatures in woody areas (Mount, 1981).

B. American Dog Tick - Newhouse (1983) found that high light intensity or low relative humidity stimulates questing behavior.

C. Rocky Mountain Wood Tick - This tick has been associated with cool soil temperatures, shallow soil, abundant leaf litter, and high relative humidity.

All of these species are attracted to carbon dioxide (CO_2), and generally prefer low light intensity and high relative humidity.

8. Medical Importance: These ticks are important because their attachment and blood-feeding can be dangerous to humans.

8.1 Direct Effects: All species may cause tick paralysis if they feed at the base of the victim's skull for extended periods. Symptoms include paralysis of the arms and legs, followed by a general paralysis which can cause death. The victim can recover completely in a few hours, after the tick is removed. Tick paralysis is mainly reported in the western U.S., but may occur whereever ticks are found. See TICK REMOVAL, below (8.3).

8.2 Indirect Effects:

A. Lone Star Ticks - The lone star tick is a potential vector of Rocky Mountain spotted fever(RMSF), tularemia, Bullis fever, the lone star virus, and Q fever.

B. American Dog Tick - The American dog tick is a vector of RMSF, St. Louis encephalitis, and tularemia.

C. Rocky Mountain Wood Tick - This species is a vector of RMSF, Colorado tick fever, tularemia, and Q fever.

The most important disease carried by these ticks is RMSF. The most characteristic symptom of RMSF is a rash on the ankles, wrists, and forehead 1-2 weeks after the victim is bitten. The rash spreads to the trunk, and is accompanied by chills, fever, and prostration. RMSF is transmitted after the tick feeds for several hours. If the tick is removed promptly, there is a smaller chance that RMSF will be transmitted.

8.3 Tick Removal: The best means to prevent the transmission of tick-borne diseases and the development of tick paralysis is prompt removal of ticks. This requires regular inspection of clothing and exposed skin for attached ticks (unattached ticks may easily be picked off without risk). To remove a tick, grasp it crosswise with narrow tweezers (do not crush or rupture the tick) as close to the point of attachment as possible. Cover it with tissue or gauze, and retract or pull tick firmly in the direction of attachment. Do not rotate the tick; some back-and-forth wiggling may be necessary. Removed ticks should be immersed in alcohol to kill them. The skin should be washed thoroughly with soap and water.

8.4 Outbreaks of Tick-borne Diseases: The diseases listed in Section 8.1 can be fatal. Any case of such a disease should be reported to medical authorities immediately. Frequent or multiple reports of tick-borne diseases should be reported to a NPS Public Health Service Representative. The representative can recommend actions to control disease outbreaks. Closing affected park areas may be advisable during such periods.

9. Natural Enemies: Several species of ants are known to feed on ticks.

III. TICK MANAGEMENT

1. <u>Population Monitoring Techniques</u>:

A. Lone Star Tick - Periodic surveys of potential or known tick habitats can reveal the presence of low-level tick infestations, and permit the application of management procedures to prevent or retard further population increase. A number of monitoring techniques have proven effective (Gladney 1978), including:

1. <u>Examination of small animal hosts trapped at selected sampling sites</u> - Live-trapped rodents may be placed in wide-mouth jars containing chloroform-saturated cotton. As soon as an animal dies, it should be removed, placed in a plastic bag, and cooled in an ice chest. Cooled animals should be shaken in 50% ethanol to kill attached ticks. Some ticks may remain attached to the animal, and must be picked off. Others may be found in the ethanol, and still others will have become dislodged in the plastic storage bag. All must be counted and identified. Larger animals may be anesthetized, visually inspected, and released. Since ticks begin to leave a dead body after a few hours, frequent visits to trap sites are required to ensure that trapped animals remain alive for sampling.

2. <u>Examination of personnel for attached ticks</u> - A volunteer wearing protective clothing walks through each sample site, and is then inspected. Ticks attached to or walking on the worker's clothing or skin are collected in 70% ethanol for later counting and identification. Careful inspection is necessary to prevent attachment of unnoticed ticks and possible disease transmission to the collector.

3. <u>Dragging</u> - A commonly-used method of off-host sampling involves dragging a white cloth over the ground or foliage where ticks are questing for passing hosts. Ticks cling to the cloth, and can be removed for counting and identification. An easily-constructed "drag" consists of a 3' x 4' sheet of white muslin, hemmed on all edges, weighted at one end, and attached to a wooden pole at the other end. A rope attached to each end of the pole allows the apparatus to be dragged across the desired sampling site. Several useful drag techniques are described by Gladney (1978). Selection of the sites to be sampled may have great effects on the efficiency of collection; lone star ticks are likely to be found in shaded areas of high humidity, while American dog ticks are most often encountered along roadways and animals runs. Sample sites should represent favored tick habitats (see

Page XXXVII-7) and sampling should be done under conditions favoring tick presence (e.g., when vegetation is not wet, and when temperatures are above 50°F).

4. Dry Ice Collection - This technique is nondestructive to small animals, requires no human "attractants", and appears to give more reproducible results than the drag technique. Ticks are collected on a cloth or plastic panel (Garcia, 1965; Mount and Dunn, 1983) containing a piece of dry ice, or on a specially constructed wood or plastic trap (Gladney 1978) containing dry ice, which is placed for a predetermined period in a selected sampling area. (Dry ice is available from most beverage and ice cream stores.) A simple technique used by Mount and Dunn (1983) involves placing a 0.5 lb block of dry ice in the center of a 2 x 3 foot panel of white polyester cloth on the ground at the chosen sampling site. After one hour, ticks on the top side of the panel are collected and/ or counted. See Gladney (1978) for descriptions of several other effective techniques.

Sampling sites should be selected in areas favoring ticks and/or which are likely to receive heavy visitation. A conscientious monitoring program is the basis of effective IPM. Regular surveys should be conducted at all sites where ticks have been reported by park staff or visitors, and at other locations which appear to be favorable tick habitats. Accurate and complete records of sample sites and methods must be kept, so that the progress of tick populations and the effect of control measures can be gauged. A sample monitoring form is presented on page XXXVII-14

2. Threshold/Action Population Level:

A. Lone Star Tick - Mount and Dunn (1983) have recommended a threshold level based on sampling by means of the CO2 technique described above. A count of 0.65 ticks per 1 hour CO2 exposure is considered the economic threshold for general use in lone star tick management (equivalent to 1 tick per visitor per day). This value may not be applicable to your particular park situation. A level can be established by conducting regular CO2 surveys, and plotting the tick counts against the numbers of tick-bite complaints received. This will permit the selection of a complaint threshold level for each site surveyed. Treatment should be conducted to keep tick populations below the selected threshold; a lower ("action") level should be selected to trigger treatment programs.

B. American Dog Tick - See 2.A. Lone Star Tick.

C. Rocky Mountain Wood Tick - See 2.A. Lone Star Tick.

3. Management Alternatives - Nonchemical:

A. Lone Star Tick

1. Outdoor Areas

Dense shrub or tree cover or tall grass provides harborage for animal hosts of ticks, and protects ticks from losing body fluids by preventing exposure to drying winds and direct sunlight. Removal of excess brush and shrubbery, and clearing of overstory trees so that between 50% and 80% of a management area is exposed to direct sunlight at any time, are recommended control practices for forested areas, walkways, parks, and landscaped grounds (Hair and Howell 1968). Grass should not be allowed to grow more than 6 inches high, to allow ventiliation and illumination of soil. Hoch et al. (1971) noted that chemical tick control was rarely needed when vegetation control was practiced. Mount (1981) obtained 76, 78, 84, and 93% control (of adult males, adult females, larvae, and nymphs, respectively), using these techniques. Visitor activities should be directed to areas unfavorable for tick habitat.

Inspection of management sites should be performed regularly to determine when application of management techniques should be conducted. Several methods of sampling outdoor sites are available, including cloth drags, trapping surveys of animal hosts, and collection methods utilizing CO2 as an attractant (See Page XXXVII-12).

2. Animal Protection

Basic principles of animal tick management include 1) isolation of susceptible animals from known tick populations, and 2) rotation of pasture or run areas, to reduce tick populations.

3. Indoor Management

The major methods of nonchemical indoor tick management include regular inspection, elimination of animal harborage areas, use of food and wastehandling procedures which will minimize animal harborage and entry, and animalproofing of each building. This includes sealing all holes in foundations and walls, and screening (with heavy-gauge metal screen) aboveground windows, vents, and other openings (smaller than 1/4 inch wide) through which animals may enter.

4. Personal Protection

Recommended practices include frequent examination of clothing (preferably by another individual) and the body (after showering), destruction of collected ticks, and the wearing of protective clothing (including high-top shoes or socks pulled over trouser cuffs, and long sleeved shirts or jackets).

5. Surveys

Periodic surveys of potential or known habitats can reveal the presence of low-level tick infestations, thus indicating the need for application of management procedures to prevent or retard further population increase. See Page 11 for useful survey techniques.

B. American Dog Tick - See 3.A. Lone Star Ticks for management techniques likely to be effective against this pest.

C. Rocky Mountain Wood Tick - See 3.A. Lone Star Ticks for management techniques likely to be effective against this pest.

4. Management Alternatives- Chemical:

A. Lone Star Tick

1. Outdoor Areas

a. Insecticide/Acaricides.--Several compounds have been shown to provide effective control of tick populations in wooded areas, fields, and other outdoor sites; these include tetrachlorovinphos, fenthion, propoxur, and sumithion. Consult your regional IPM Coordinator to determine which pesticide, if any, is best suited to your tick control program.

b. Herbicides.--Herbicides have been suggested for use in brush, shrub, and overstory growth management, to eliminate harborages for animal hosts of ticks, and reduce humidity and shade which protect ticks from dessication in their habitats.

2. Protection of Personnel

Schreck et al. (1980) reported that application of the tick repellent chemicals DEET, M-1960 (a military formula) and permethrin provided good protection (81, 95, and 89%, respectively) against the lone star tick. DEET and M-1960 were found to be irritating to wear, and have disagreeable odors. Mount and Snoddy (1983) showed that application of pressurized sprays of 20% DEET to the exterior surfaces of clothing provided 85% protection against the Lone Star Tick (adults and nymphs) and 94% protection against the adult American Dog Ticks. They found that sprays of 0.5% permethrin gave 100% protection against both species; however, permethrin is not currently registered for either use so cannot be recommended at this time. DEET is available in several commercial products (e.g. Off, 6-12, Cutter's Insect Repellent). M-1960 is a mixture of the following:

30% N-butyl acetanilide;
30% 2-Butyl-2-ethyl-1,3-propanediol;
30% Benzyl benzoate; and
10% Tween 80 (an emulsifier).

3. Indoor Areas

Sites such as crevices; basebords; trimming; furniture; ceilings, high places; floors/carpets; behind pictures, bookshelves and drapes should be spot-treated (as needed) with:

0.25% bendiocarb, or
0.50% diazinon, or
1-2 % malathion (Mallis, 1982).

Fumigation may be successful in indoor sites; however, available fumigants are very dangerous, and must be applied by a certified applicator (as must bendiocarb sprays for spot treatments).

B. American Dog Tick - Little information regarding the control of *D. variabilis* is available. Koch and Burkwhat (1983) reported that propoxur and bendiocarb were the most effective pesticides against nymphs in laboratory studies; no field tests have been reported. See 4.A. Lone Star Ticks for management techniques likely to be effective against this pest.

C. Rocky Mountain Wood Tick - See 4.A Lone Star Tick for potentially useful control procedures.

5. Summary of Management Recommendations:

A. Lone-Star Tick- For tick management in outdoor areas, habitat reduction by removal of excess brush, clearance of dense overstory cover, and regular mowing of grassy areas to 6 inches or less in height is recommended. Regular CO_2 surveys of likely tick habitats will indicate locations where treatment is necessary. If nonchemical measures prove ineffective, registered herbicides (for habitat modification) and acaricides (such as chlorpyrifos or fenthion, for reduction of heavy infestations) may be needed during the first years of the program.

Animalproofing of park buildings (following chemical treatment of existing infestations) should eliminate habitats for tick hosts, reducing the chance of future infestations.

Recommended procedures for protection of park personnel and visitors include frequent examination of the clothing and body of any person travelling in tick habitats, the wearing of protective clothing, and the use of clothing and/or skin-applied tick repellants.

Information should be made available to park visitors concerning:

- Known tick habitats within the park;
- Personal protection techniques (protective clothing, tick repellants);
- Tick removal techniques.

B. American Dog Tick- See 5.A. Lone-Star Tick.

C. Rocky Mountain Wood Tick- See 5.A. Lone-Star Tick.

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Schreck, C.E., E.L. Snoddy, and G.A. Mount. 1980. Permethrin and repellents as clothing impregnants for protection from the lone star tick. J. Econ. Entomol. 73:436-439.

United States Department of Health, Education and Welfare. 1967. Pictorial keys to arthropods, reptiles, birds and mammals of public health significance. U.S. Dept. of Health, Education and Welfare, Washington, D.C. 192 pp.

V. SAMPLE TICK MONITORING FORM

Date:__________ Area:____________ Recorded by:________________________________

Sketch map of survey area:

N
W--|--E
S

- Show area dragged or placement of dry ice traps.
- Include any areas considered important, such as camping, picnic, trail areas, etc.
- Indicate type of survey conducted (check one):
  ___ Personal Examination
  ___ Host Animal Trapping
  ___ Drag Count
  ___ Dry Ice Trapping

Survey results:

1. Details of method (length of drag path, duration of CO_2 trapping, size of cloth, etc.):

2. Tick count:

Species	Lone Star Tick	American Dog Tick	Rocky Mt Wood Tick
# Larvae			
# Nymphs			
# Adults			

3. Proposed treatment:

4. Date treated:________________________ Treated by:________________________________

5. Comments:

NATIONAL PARK SERVICE
IPM Information Package

WEEDS OF DEVELOPED AND HISTORIC SITES

Final Report

30 August 1984

Submitted To:

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

Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

CONTENTS

I. WEED IPM DECISION TREE

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

START

↓

What is your weed problem?

↓

Weeds have been found in/on
structures, earthworks, etc.

→ YES → Go to page XLIII-3.

↓

NO

↓

Weeds have been found in
landscaped areas.

→ YES → Go to page XLIII-4.

↓

NO

↓

You wish to establish a
preventative program to minimize weed
problems in structures.

→ YES → Go to page XLIII-5.

↓

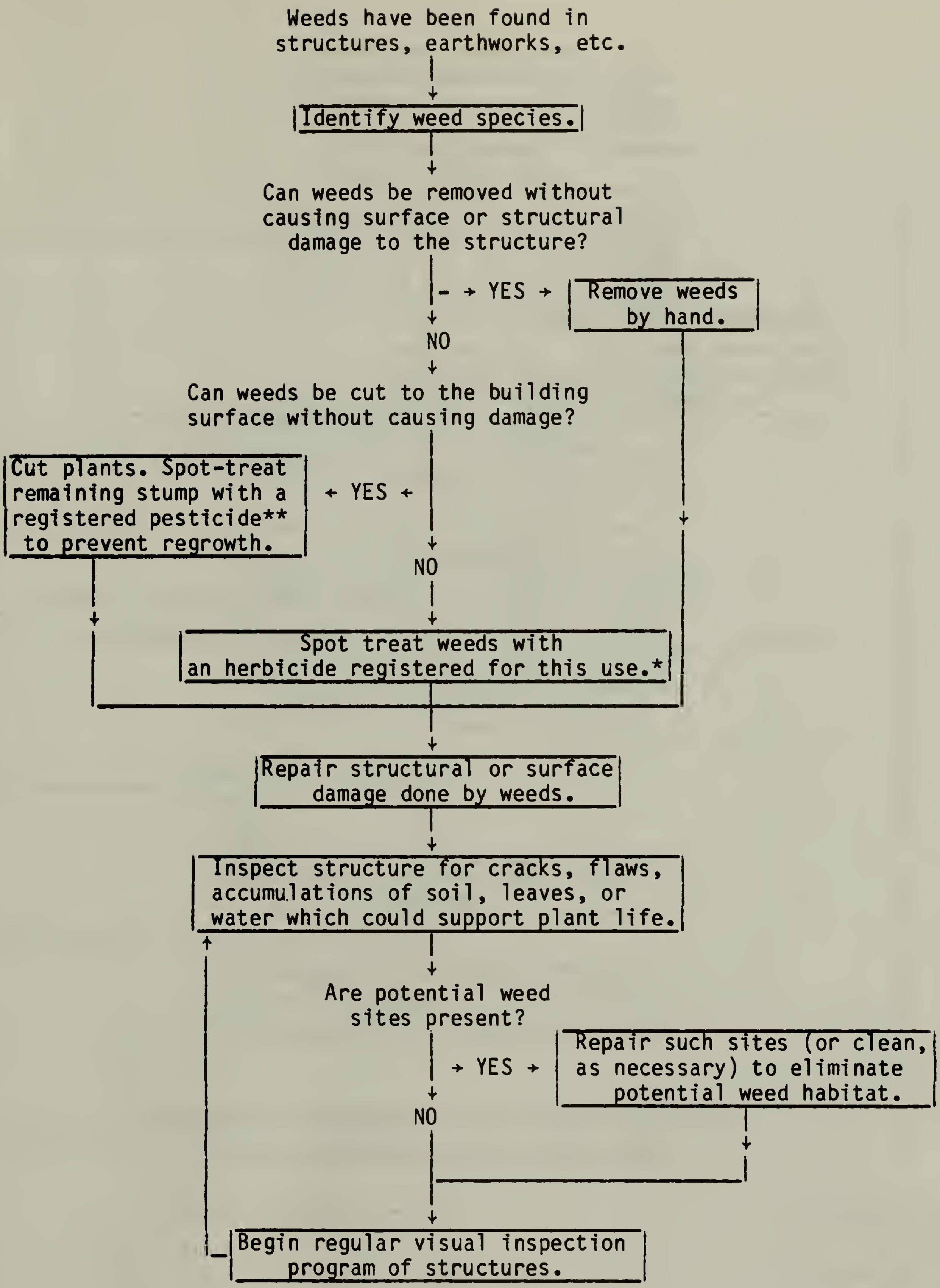
NO

↓

You wish to establish a preventative
program to minimize weed problems in
landscaped areas.

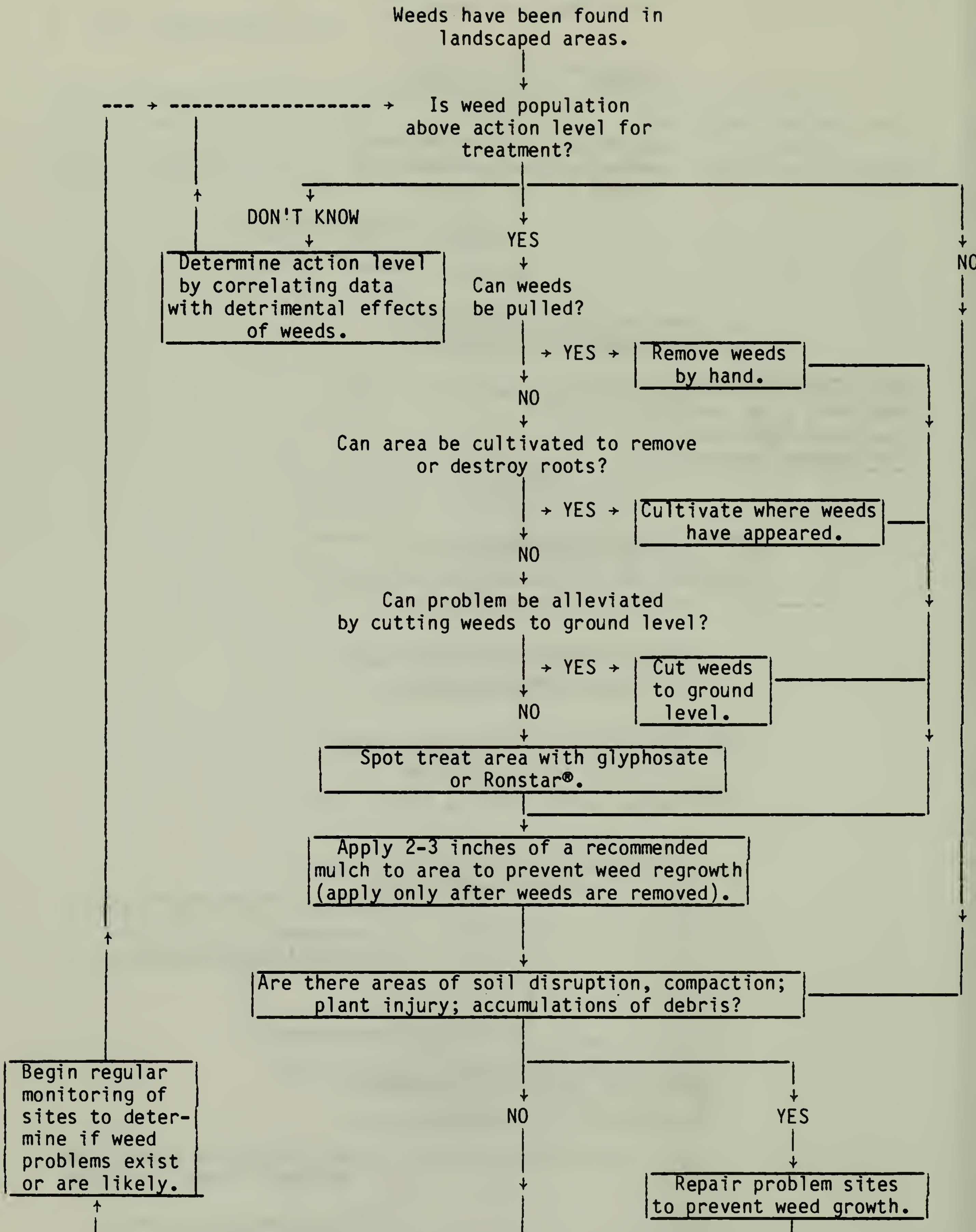
↓

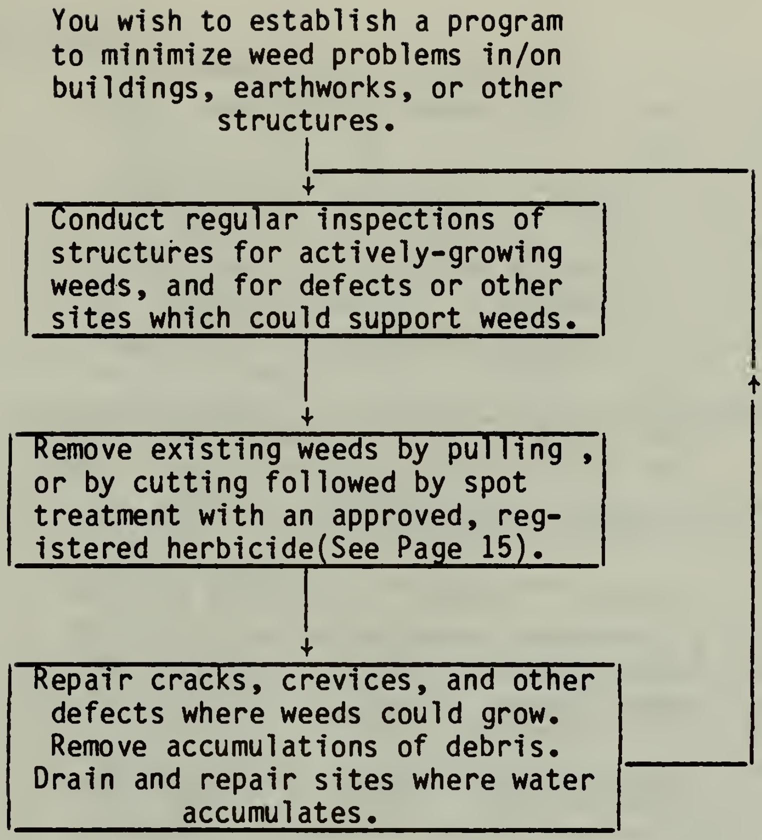
Go to Page XLIII-6.



*Use glyphosate or ammonium sulfamate (Page XLIII-16).

**Use ammonium sulfamate (Page XLIII-16).


Weeds have been found in landscaped areas.
Is weed population above action level for treatment?
DON'T KNOW
Determine action level by correlating data with detrimental effects of weeds.
YES
NO
Can weeds be pulled?
YES
Remove weeds by hand.
NO
Can area be cultivated to remove or destroy roots?
YES
Cultivate where weeds have appeared.
NO
Can problem be alleviated by cutting weeds to ground level?
YES
Cut weeds to ground level.
NO
Spot treat area with glyphosate or Ronstar®.
Apply 2-3 inches of a recommended mulch to area to prevent weed regrowth (apply only after weeds are removed).
Are there areas of soil disruption, compaction; plant injury; accumulations of debris?
NO
YES
Repair problem sites to prevent weed growth.
Begin regular monitoring of sites to determine if weed problems exist or are likely.

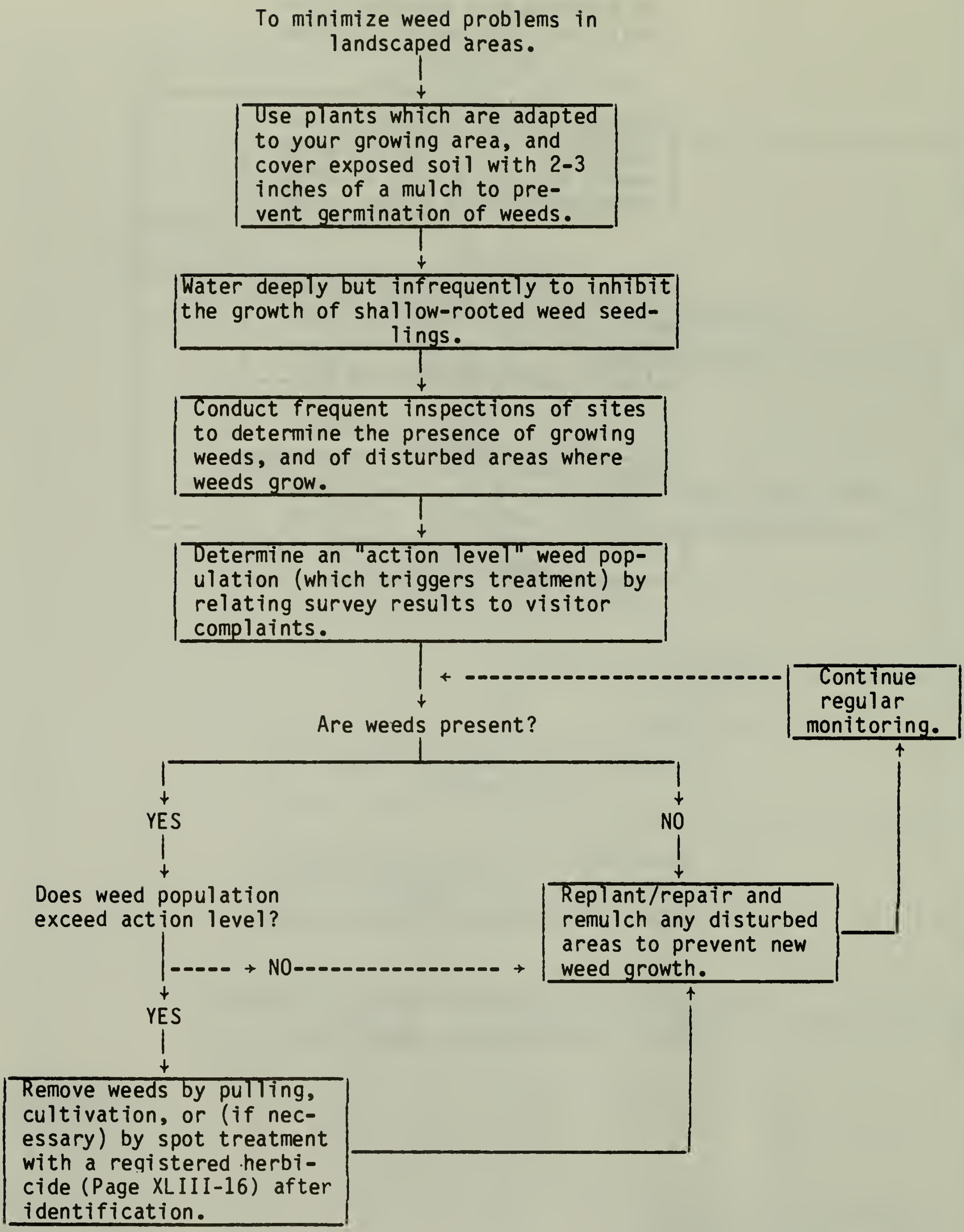


You wish to establish a program to minimize weed problems in/on buildings, earthworks, or other structures.

Conduct regular inspections of structures for actively-growing weeds, and for defects or other sites which could support weeds.

Remove existing weeds by pulling , or by cutting followed by spot treatment with an approved, registered herbicide(See Page 15).

Repair cracks, crevices, and other defects where weeds could grow. Remove accumulations of debris. Drain and repair sites where water accumulates.


To minimize weed problems in landscaped areas.
Use plants which are adapted to your growing area, and cover exposed soil with 2-3 inches of a mulch to prevent germination of weeds.
Water deeply but infrequently to inhibit the growth of shallow-rooted weed seedlings.
Conduct frequent inspections of sites to determine the presence of growing weeds, and of disturbed areas where weeds grow.
Determine an "action level" weed population (which triggers treatment) by relating survey results to visitor complaints.
Are weeds present?
Continue regular monitoring.
YES
NO
Does weed population exceed action level?
Replant/repair and remulch any disturbed areas to prevent new weed growth.
NO
YES
Remove weeds by pulling, cultivation, or (if necessary) by spot treatment with a registered herbicide (Page XLIII-16) after identification.

II. WEED BIOLOGY AND ECOLOGY

1. Species Described: Weeds are generally described as any plants growing where they are not wanted. Nearly any plant species can be considered a weed depending on its location; the description of each potential weed species is beyond the scope of this document. We suggest that you contact the United States Dept. of Agriculture Cooperative Extension Service in your state for information on the most important weeds in your region. A list of useful pictorial weed guides is included in the Bibliography section of this report.

2. Geographic Distribution: As defined above, weeds are found wherever humans interact with an environment which will support plant growth.

3. Habitat: Two habitats will be considered in this report; landscaped areas (where natural vegetation has been replaced or augmented with other plants, usually for aesthetic purposes), and buildings. Weeds growing in landscaped areas are found where soil has been exposed or disturbed by traffic or planting activities; where the desired plants are weakened by adverse environmental conditions, diseases, or pests to the extent that they cannot compete for nutrients, water, or light with "weed" species; where the desired plantings are not as well adapted to their environment as are native or exotic "weed" species; and where the growth of the desired plants modifies their local environment so that natural ecologic succession to "weed" species can occur (in the absence of control).

   Buildings, ruins and other artificial sites can be considered disturbed environments, which (in the absence of control measures) over time will become populated by pioneer plant species, and which will undergo succession to a plant community characteristic of the region in which the site is located. As in normal succession, pioneer species (e.g., mosses, some annual herbs) can become established anywhere that a suitable substrate and water source are found. Gutters; cracks in roofs, walls and foundations; chinks in masonry or stones; gravel roofs; and ledges may accumulate mosses and lichens. Where dust, soil, or other debris accumulates in crevices, recesses, and depressions, higher plants can root. Generally, these are a random assortment of adapted species from the local area plus a few rock-adapted species.

In soil pockets or deep cracks and crevices, woody plants can take root.

4. Hosts:

Most weed plants (including flowering plants, ferns and their relatives, mosses, and lichens) grow on soil or rock, thus do not have hosts *per se*. Parasitic plants make up a very specialized group, the description of which is beyond the scope of this document.

5. Life Cycles:

The life cycles of flowering weeds (the most common types) can be divided into four major groups:

A. Summer annual weeds (e.g., morning glory, ragweed, and crabgrass) grow each spring or summer from seed. They grow, mature, produce seeds, and die in one growing season. Seeds generally overwinter before germinating the following spring.

B. Winter annual weeds (e.g., field pepperweed, shepherds-purse) germinate in late summer or fall from seed, then mature and produce seed the following spring or summer. Seeds of most of these species are dormant during the spring. Some species (e.g., chickweed) can germinate under snow cover, and produce new seed by May or June, allowing two generations per year.

C. Biennial weeds (e.g., wild carrot, bull thistle) may germinate at any time during the growing season. They usually produce a rosette of leaves close to the soil during the first season, then flower (using energy stored during the first season's growth), mature, and die during the next year.

D. Perennial weeds (e.g., dandelion, vines, shrubs, trees) become established by seed or vegetative parts (e.g., roots, tubers, rhizomes). Once established, they live for more than two years, and often for many years.

Lower plants will generally fall into one of the above general life cycle types, with reproduction by seed, spore, or vegetative plant part. Multiple yearly generations may occur in some species.

6. Seasonal Abundance:

Perennials, biennials, and annuals may all exhibit foliar growth during the spring, summer, and fall. Certain perennials, biennials, and winter annuals will retain their foliage through the winter. The relative proportions of these types of weeds varies according to geographic, ecologic, and climatic characteristics of the region of concern.

7. <u>Response to Environmental Factors:</u>

Critical environmental factors for plants (including weeds) include temperature, light intensity and spectrum, atmospheric moisture level, soil moisture, substrate composition, substrate texture, types and availability of nutrients, competition from other plants, and antagonism by other organisms. Each plant species will grow best under a specific level (or range) of each of these factors. The range of acceptable environments among those plant species in any given region is always great enough to guarantee that any site which becomes able to support plant life will eventually be colonized by species able to make use of the conditions available.

Certain nonchemical control methods are designed to limit or prevent weed growth by limiting one or more of these critical factors (e.g., mulching and cultivation, which keep light from weed seeds, preventing their germination). These methods are described in Section III.3. of this report.

8. <u>Impact of Weeds:</u>

8.1 Direct Impact

The direct impacts of weeds on landscaped areas include:

A. Competition with and replacement of desired plants by better-adapted weed species.

B. Creation of unsightly patches of growth and/or dead areas when annuals overgrow desired plants and then die (e.g., annual dropseed grass).

C. Toxicity to humans and animals. Many common weeds are poisonous if consumed (e.g. Johnsongrass, pokeweed), or may cause inflammation when touched (e.g., stinging nettle, poison ivy, oak, and sumac), or may cause allergic reactions (e.g., common ragweed and many grasses).

D. Creation of nuisance conditions causing visitor discomfort (e.g., covering of trails or signposts by fast-growing species, or visitor injury due to spines or thorns of many weed species).

E. Necessity for increased expenditures for landscape maintenance to control weed population.

Direct impacts of weeds growing on/in buildings and other structures include:

A. Structural damage caused by plant growth between boards or bricks, leading to separation of walls or other parts.

B. Destruction of earthworks due to root penetration;

C. Obstruction of structures and historic landscapes and vistas due to overgrowth of surfaces by weeds.

D. Staining of building surface or facing materials.

8.2 Indirect Impact: Weeds can serve as secondary hosts for microbes and insects which may damage desirable plantings. Weedy areas may also become habitats for rodents and arthropods (e.g., rats, ticks, mites, mosquitoes, biting flies) which attack humans and domestic animals, and/or carry diseases affecting humans and other animals.

9. <u>Natural Enemies:</u> Weed species are subject to attack by many natural enemies, including herbivorous mammals, reptiles, birds, and insects; disease organisms such as fungi, bacteria, nematodes, viruses, and spiroplasmas; and allelopathic plants (which produce chemicals inhibitory or toxic to the weed). Plant species better adapted than the weed to the particular growing site may out-compete and replace a weed species. Certain antagonistic organisms have been adapted for biocontrol of specific weeds in aquatic and agricultural situations (e.g., biocontrol of waterhyacinth by exotic insects and a fungus). However, no adapted biocontrol agents are currently available commercially for control of weeds on structures, or in ornamentals or turf.

III. WEED MANAGEMENT

1. <u>Population Monitoring Techniques</u>: Integrated weed management is not yet a highly-developed discipline. To date, the best technique for monitoring weed populations is visual observation:

A. On structures, earthworks - Conduct regular (weekly) inspections of all structures for the presence of weed growth, extent of damage that can be correlated with the presence of plant growth, and structural defects that could be colonized by weeds.

B. In landscaped areas - Conduct regular (weekly) inspections throughout the growing season for the presence of actively growing weeds, and areas where the plantings have been disturbed in such a way that the sites could support new weed growth. Such disturbances include:

- o Cultivation (which can expose previously buried weed seeds to light);
- o Soil exposure due to visitor traffic or mulch removal;
- o Flooding;
- o Drought;
- o Soil compaction (due to pedestrian or vehicular traffic);
- o Infestations of plant diseases or insects;
- o Accumulations of leaves or other debris;
- o "Dog Blight", caused by animal urine.

Additional inspections during the winter (or fallow periods) should be made for signs of new weed growth, or of other damage to plantings (which could make the site favorable for weed growth).

2. <u>Threshold/ Action Population Levels:</u>

A. On structures - For the majority of historic or other structures, an appropriate threshold level (above which some damage can be expected) is zero weeds. On ruins and earthworks, levels should be set to prevent structural damage, aesthetic interference and visitor complaints.

B. In landscaped areas - It is extremely difficult to set specific threshold population levels for weeds in landscaped sites, since the problems caused by weeds are largely aesthetic, rather than medical or economic. Each park manager should establish threshold and action levels for his/her own area by correlating records of weed populations with visitor complaints (of visual nuisance, traffic obstruction, and/or injury).

3. <u>Management Alternatives - Nonchemical:</u>

A. On structures

1. <u>Mechanical methods</u>

   a. Weed removal - Weeds should be removed by hand where possible, and where their removal will not result in further damage to the infested structure (e.g., if pieces of mortar are pulled out with the weed, do not pull any more!). Trees or shrubs growing on ruins or earthworks should not be removed until it can be determined that their removal will not cause more damage than would their continued growth. If weeds are removed, stabilization procedures should begin after removal.

   b. Cutting - Weeds which cannot be completely removed from the affected structure can be cut as much as possible. However, frequent monitoring for regrowth will be required. Vines should be kept away from rain gutters, window or door sashes, or other exposed wood.

   c. Maintenance of buildings - Frequent building inspection should be conducted to discover cracks, crevices, accumulations of debris or water, and other sites which could support weed growth. When found, such areas should be cleaned and/or repaired, to prevent future weed growth.

B. In landscaped areas

1. Mechanical methods

   a. Weed removal - Established weeds can be removed by hand.

   b. Cutting - Weeds can be cut to ground level, but will generally regrow. Repeated cutting may weaken some weeds by draining nutrient reserves from their roots. Cutting will keep annual weeds from producing new seeds if it is performed before flowering.

   c. Cultivation - Cultivation of soil around landscape plantings can bury weed seeds (many of which need light to germinate), break-up and smother weed seedlings, and weaken perennial weeds by removal of foliage and roots.

2. Physical methods

   a. Heat treatment - Since weeds (and other plants) are killed by exposure to temperatures above 113-131°F, fire has been used (i.e., as flame throwers) to control weeds along rights of way. This control method is probably not suited for use at most park sites.

      Weed seeds in soil can be killed (along with other microbes) by treating the soil with aerated steam (Aldrich et al., 1972) before it is used for plantings. While this method is effective for conservatory and other small plantings, it is usually too expensive for large-scale outdoor use.

3. Cultural methods

   a. Flooding - This method has certain uses in agricultural systems, but is not applicable to most park situations.

   b. Mulching - Among the other advantages of the use of mulches (e.g., thermal insulation, increased water-holding capacity, retardation of evaporation of soil moisture), these materials will eliminate or retard weeds by eliminating the light that weed seeds require for germination. Mulches should be applied to planted areas in mid-spring when the soil is warm enough for active root growth.

Mulches should be at least 2-3 inches deep over the treated area, but should not contact stems or trunks of desirable plants (to keep the plants free of wet spots where disease organisms can grow). Certain mulches may contain weed seeds (e.g., hay, straw, and strawy manures) and should be avoided. Some recommended mulches are:

- Sphagnum peat moss - Ideal for mulching acid-loving plants such as evergreens. Good color, and remains effective 1-2 years.
- Bark (shredded) - Good texture, long effective life. Excellent for all plants.
- Crushed stone - Available in various colors. Long lasting. Some types (e.g., limestone) may alter soil pH levels.
- Black polyethylene - Unsightly. Must be held in place to prevent wind from carrying the material away.
- Crushed corncobs - Additional fertilization of plantings may be required if this mulch is used.
- Buckwheat hulls - Long lasting, good color; may blow away in windy areas.
- Dark, rotted sawdust - Preferable to fresh sawdust; some nitrogen must be added to soil if this is used.
- Fiberglass mats - Will not rot, corrode, or burn; long lasting.
- Other materials - Spent hops, lawn clippings, leaves (especially oak, since they do not pack down too closely), cocoa bean hulls, leaf mold, and paper pulp have all been used for mulching.

- o Living mulches - Certain ground cover plants are effective in landscaped areas as living mulches which shade the surface soil, and aid in soil water retention. These include Euonymus varieties, Vinca, honeysuckle, Ajuga, Phlox subulata, bedding petunias, annual alyssum, Sedum varieties, and native ferns.

Consult your local USDA Cooperative Extension Service agent for details on preferred materials for your region.

4. Biological control - No biological control agents have been approved by the U.S. Environmental Protection Agency for use in landscape or structural situations. However, the use of nonchemical control methods (or chemicals with a limited host range) for control of insects and other pests will permit naturally-occurring weed controls to operate at maximum effectiveness.

4. **Management Alternatives - Chemical:**

Many herbicides are currently registered for the control of weeds in ornamental plantings, and for structural applications. The choice of the chemical to be used on a particular site should follow the key shown here:

- A. Weeds near water.......................... Rodeo® or Ammate®.
- B. Weeds not near water.
  - 1. Selective herbicides.
    - a. For grasses.
      - i. For annual grasses.
        - aa. In grass.............siduron.
        - bb. In broadleafs....... dalapon or oryzalin.
      - ii. For perennial grasses.
        - aa. In grass............ triazines.
        - bb. In broadleafs....... dalapon.
    - b. For broadleafs.
        - aa. In grass............ MCPP, 2,4-D.
        - bb. In broadleafs....... Spot treat with Roundup®.
  - 2. Nonselective herbicides...............NEXT PAGE.

2. Nonselective herbicides.
    a. For annuals...................... Mechanical treatment is recommended.
    b. For perennials.
        i. Herbaceous spp............. Roundup or Ammate or simazine(pre-emergence).
        ii. Woody spp.................. Roundup or Ammate.

Contact your NPS IPM Coordinator for additional information concerning which, if any, of these products is best for your particular weed management requirements.

5. Summary of Management Recommendations:

Effective weed control in landscaped ares and in/on park structures involves the following procedures:

A. Regular monitoring of all sites for weed growth, and for signs of disturbance (e.g., building cracks, compacted or exposed soil, dead plants, and accumulations of debris) which could promote or support weed growth.

B. Maintenance of sites so that such disturbances are prevented or repaired. This includes repair of building defects, mulching of landscaped areas, removal of accumulated debris, and the use of plantings which are well-adapted to their site, so that they will be less likely to be overgrown by weed species.

C. Removal of weeds, when found. Mechanical procedures such as pulling or cultivation will often eliminate the problem. Spot treatment with a registered, approved herbicide may be necessary to destroy certain annual or perennial weeds.

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Consult your local USDA Cooperative Extension Service agent, State University, or regional IPM coordinator for weed identification guides and services specific for your area.

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NATIONAL PARK SERVICE
PEST MANAGEMENT REPORT

YELLOWJACKETS

Final Report

31 July 1984

Submitted To:

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Environmental Protection Agency
Arlington, Virginia 22202

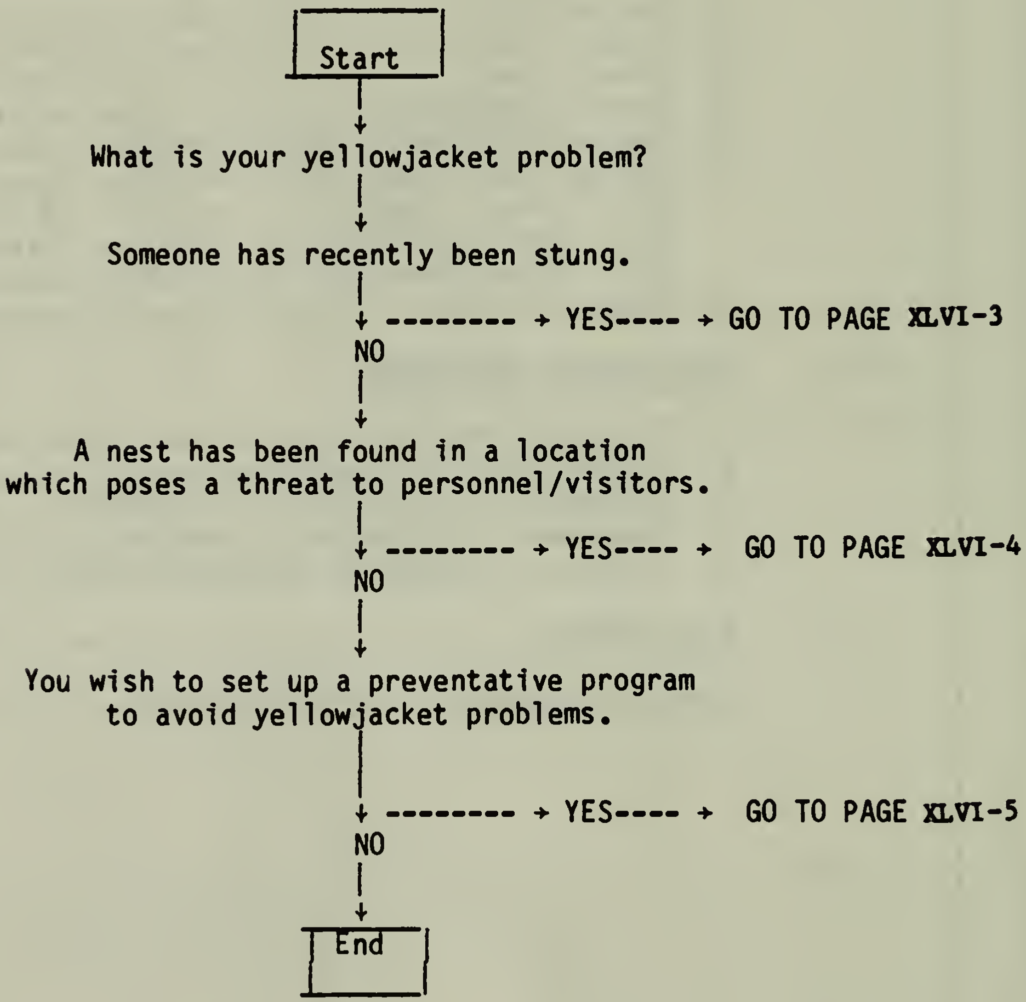
Submitted By:

Dynamac Corporation
11140 Rockville Pike
Rockville, Maryland 20852

CONTENTS

I. YELLOWJACKET IPM DECISION TREE

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



Start

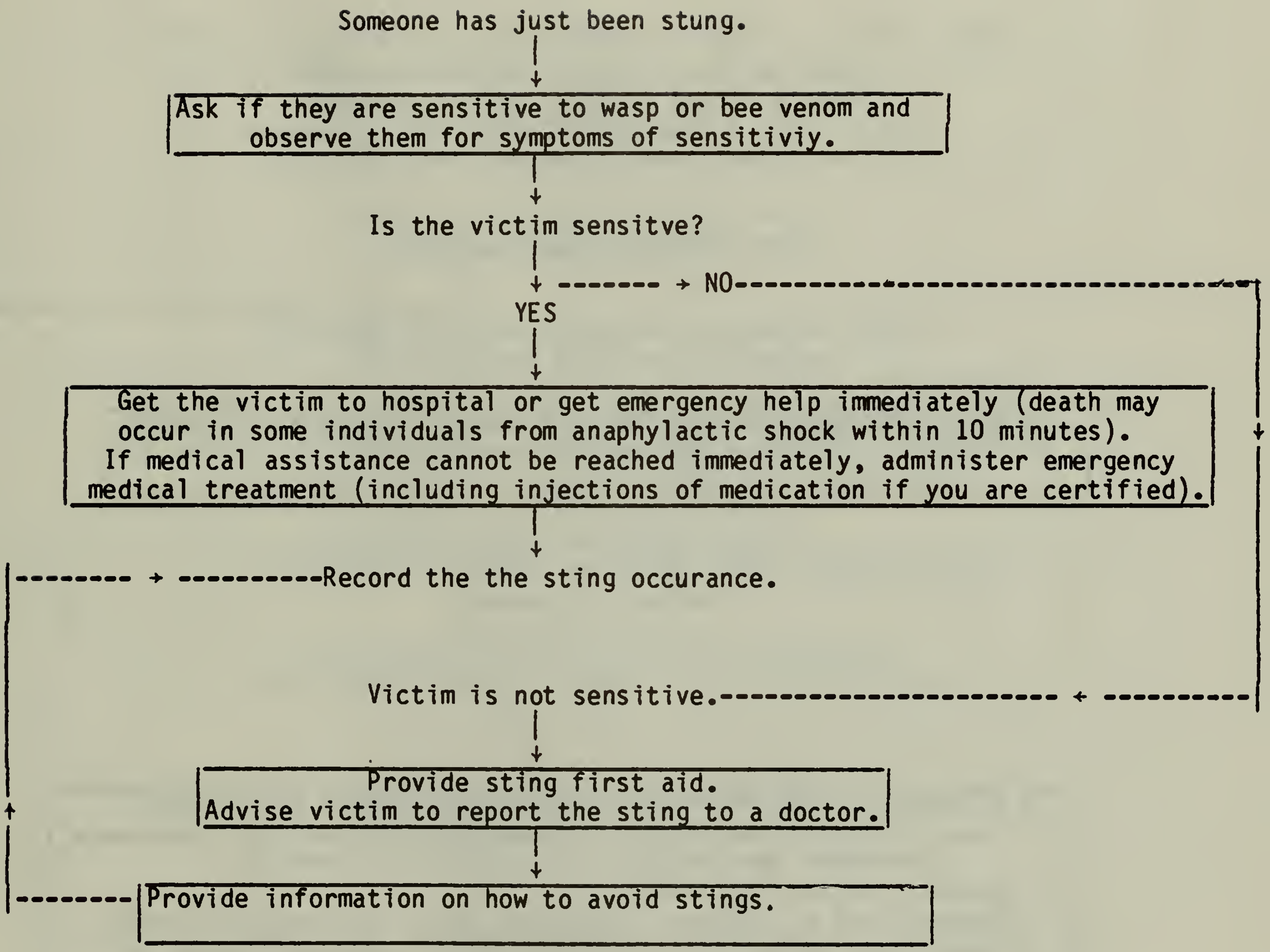
What is your yellowjacket problem?

Someone has recently been stung.
→ YES → GO TO PAGE XLVI-3
NO

A nest has been found in a location which poses a threat to personnel/visitors.
→ YES → GO TO PAGE XLVI-4
NO

You wish to set up a preventative program to avoid yellowjacket problems.
→ YES → GO TO PAGE XLVI-5
NO

End



Someone has just been stung.

Ask if they are sensitive to wasp or bee venom and observe them for symptoms of sensitiviy.

Is the victim sensitve?

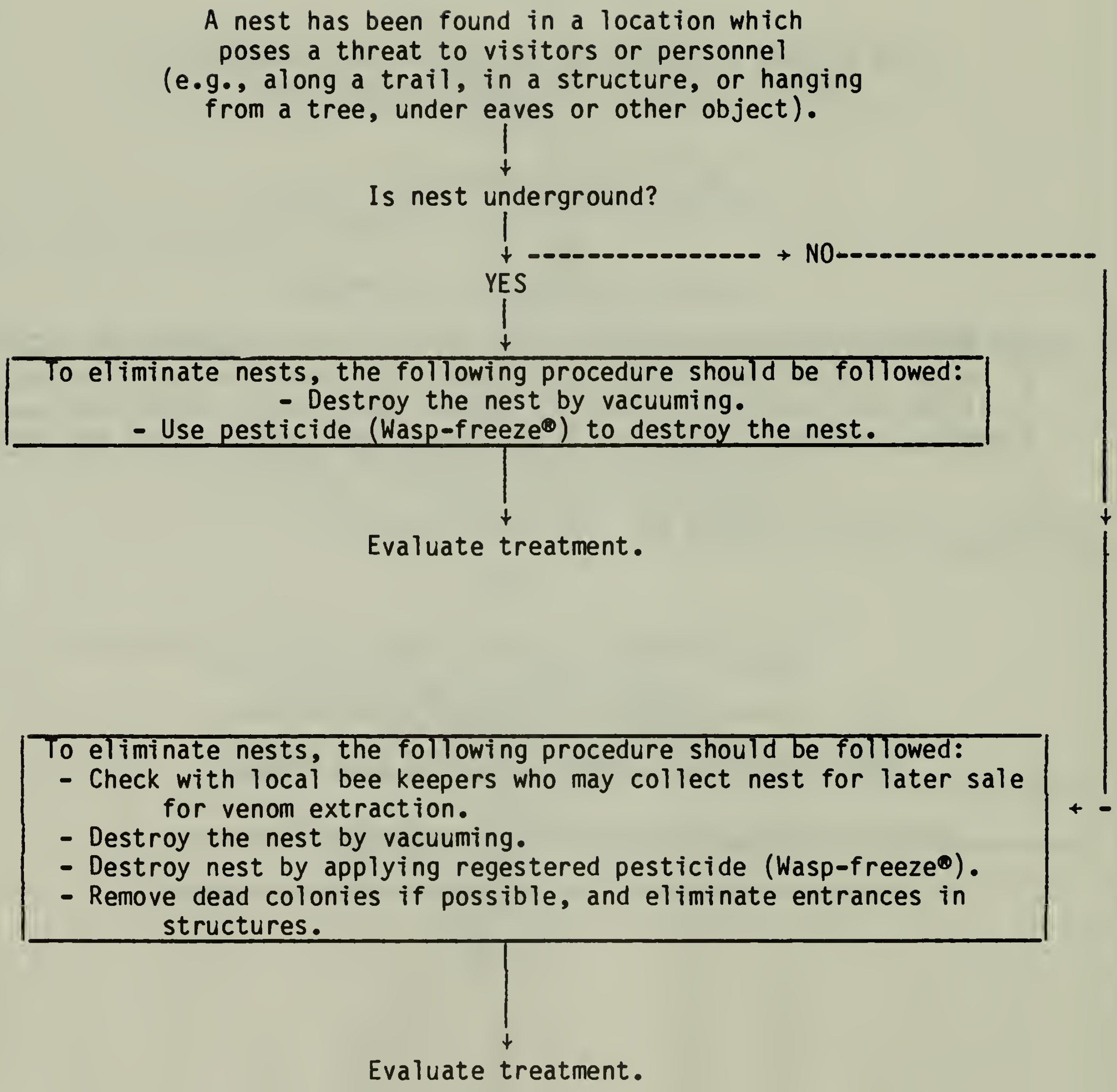
Get the victim to hospital or get emergency help immediately (death may occur in some individuals from anaphylactic shock within 10 minutes). If medical assistance cannot be reached immediately, administer emergency medical treatment (including injections of medication if you are certified).

Record the the sting occurance.

Victim is not sensitive.

Provide sting first aid.
Advise victim to report the sting to a doctor.

Provide information on how to avoid stings.



A nest has been found in a location which
poses a threat to visitors or personnel
(e.g., along a trail, in a structure, or hanging
from a tree, under eaves or other object).

Is nest underground?

NO

YES

To eliminate nests, the following procedure should be followed:
- Destroy the nest by vacuuming.
- Use pesticide (Wasp-freeze®) to destroy the nest.

Evaluate treatment.

To eliminate nests, the following procedure should be followed:
- Check with local bee keepers who may collect nest for later sale for venom extraction.
- Destroy the nest by vacuuming.
- Destroy nest by applying regestered pesticide (Wasp-freeze®).
- Remove dead colonies if possible, and eliminate entrances in structures.

Evaluate treatment.

You wish to set up a preventative program to avoid stings.

↓

Learn pest biology.

↓

Find out what pest species are in
your area and where they nest.

↓

Determine (by site visit) if a problem exists,
what species are present (and at
what time of the season), where they are nesting (if possible)
and are foraging, and why they are present
(ie. what human activities are responsible for their presence).

↓

|--- → --------------Monitor: record stings; counts
at garbage containers and traps (where appropriate).

↓

Set injury levels/thresholds for number of
tolerable stings and numbers of foraging workers.

↑ ↓

Take steps to reduce human-yellowjacket
contacts; lids on trash containers,
lids on soft drinks at concessions,
frequent trash pick-up (especially on weekends).

↓

|---- ← -------Evaluate and (if necessary) modify your program.

II. YELLOWJACKET BIOLOGY AND ECOLOGY

1. **Species Described:**

Yellowjackets (*Vespula*, *Dolichovespula*, *Vespa*) are colonial wasps which build enclosed paper nests underground, in trees or structures. While many other species of wasps, such as paper wasps (*Polistes*), may build nests in dangerous places (i.e.: under building eaves), they are not considered pestiferous in most circumtances.

Of the 19 species of yellowjackets and hornets found in North America, only 5 are considered to be pestiferous:

A. Eastern yellowjacket - *Vespula maculifrons* (Buysson)

B. Southern yellowjacket - *V. squamosa* (Drury)

C. German yellowjacket - *V. germanica* (Fab.)

D. Common yellowjacket - *V. vulgaris* (L.)

E. Western yellowjacket - *V. pensylvanica* (Saussure)

Other species may from time to time become troublesome or (more commonly) build nests in dangerous places (along trails, under eaves, etc.). The species considered pestiferous are all scavangers (especially late in the year) and foragers which come into contact with people frequently. All yellowjackets, including scavenging species, should be considered beneficial due to their predaceous habits and their consumption of large quantities of insects.

See pages 100-119 of U.S. Department of Health, Education, and Welfare (1967) for keys to stinging hymenoptera of the U.S. Also see Akre et al. (1981) for detailed keys to yellowjackets of North America.

2. **Geographic Distribution:**

A. Eastern yellowjacket - Eastern to central U.S., rarely to Colorado.

B. Southern yellowjacket - Southeastern U.S., north to Pennslyvania, west to central Texas and Iowa.

C. German yellowjacket - Introduced from Europe, Northeastern U.S. Moving west, reported from Illinois and Ontario to Georgia.

D. Common yellowjacket - Northern North America, south in Appalachians to Georgia, south on Pacific Coast to Los Angeles, south in Rockies to Mexico. Introduced to Hawaii (Maui).

E. Western yellowjacket - Western U.S. to Nebraska, rarely to Wisconsin. Introduced to Hawaii (Kawai, Oahu, Maui, Hawaii).

3. Habitat:

A. Eastern yellowjacket - Nests mainly in ground, occassionally in wall voids. Queens overwinter in rotten logs or soil litter and begin a new colonies in abandoned rodent burrows or in air pockets under logs or stones. Nests typically are located in forests and open areas, but the boundary between forest and field or path is favored. Nests are used only once.

B. Southern yellowjacket - Nests in ground, as per eastern yellowjacket; may be social parasite.

C. German yellowjacket - Nests almost exclusively in wall voids in North America; rarely subterranean.

D. Common yellowjacket - Nests in ground, rotten logs or stumps throughout range. May nest in walls in western U.S.

E. Western yellowjacket - Nests primarily in ground; may nest in attics or in walls.

4. Hosts:

A. Eastern yellowjacket - Feeds on insects for most of the year. Some foragers scavange dead insects and other animals, others capture live prey. Often scavanges sweets, especially when colony is at maximum population size late in the season.

B. Southern yellowjacket - This species often socially parasitizes nests of 4.A. (eastern yellowjacket), killing the resident queen and usurping the colony.

C. German yellowjacket - Same as 4.A. (eastern yellowjacket)

D. Common yellowjacket - Same as 4.A.(eastern yellowjacket)

E. Western yellowjacket - Same as 4.A.(eastern yellowjacket)

5. Life Cycles:

A. Eastern yellowjacket - The newly produced queens are the only members of the colony to survive the winter (except in some situations in Florida).

Sometime from late March to May, they emerge from hibernation. Fertilized by males the previous autumn, the queen lays approximately 45 to 70 eggs which will hatch and become the first generation of workers. The queen continues oviposition and forages and cares for her first brood. When the first 5 to 7 brood emerge, they function as workers and care for all subsequent brood. The queen does not leave the nest again. Workers feed the young, expand the underground nest by digging (the queen does not dig), produce paper comb, and protect the nest. Unlike bees, where worker age determines duties, yellowjackets can and do perform all duties at all ages (Davis, 1978). Also unlike bees, yellowjacket workers are not sterile but are kept from laying and caring for their own progeny by inhibitory chemicals (pheromones) produced by the queen. If the queen is lost, workers will produce male offspring.

B. Southern yellowjacket - Same as 5.A.(eastern yellowjacket)

C. German yellowjacket - Same as 5.A.(eastern yellowjacket)

D. Common yellowjacket - Same as 5.A.(eastern yellowjacket)

E. Western yellowjacket - Same as 5.A.(eastern yellowjacket)

6. Seasonal Abundance:

A. Eastern yellowjacket - Colonies grow slowly until mid-summer when successive broods of workers emerge and growth becomes exponential. Pest species typically have 500-5,000 workers at peak population. In late summer, new queens and males are produced. Queens mate and go into hibernation. After queens and males have left, the colony declines in population, with fewer workers being produced. Existing brood are usually discarded or fed to other larvae in the colony. Foraging workers are more likely to sting at this time.

Maximum worker numbers result in many workers foraging in picnic areas and trash cans for discarded soft drinks and other foods. Increased activity in areas frequented by human beings, coupled with increased aggressiveness and willingness to sting, leads to a sharp upsurge in the number of stings in late summer and fall (Davis, 1978).

With the advent of cold weather, the old queen and workers die (the mated queens go into hibernation very early).

B. Southern yellowjacket - Same as 6.A.(eastern yellowjacket)

C. German yellowjacket - Same as 6.A.(eastern yellowjacket)

D. Common yellowjacket - Same as 6.A.(eastern yellowjacket)

E. Western yellowjacket - Same as 6.A.(eastern yellowjacket)

7. Response to Environmental Factors:

Yellowjacket populations are influenced by weather. Cold, wet winters are unimportant, but sudden cold snaps in springtime may severely reduce colony survival. In studies with western species it has been demonstrated that cold periods during the critical first brood phase are the most important single factor determining yellowjacket abundance (Davis, 1978).

Queens compete for nesting areas in early spring. Several queens may attempt to usurp the nest of another and it is not uncommon to find the carcasses of more than one queen in the entrance of a small nest.

8. Medical importance:

8.1. Direct Effects:

Those individuals who are not sensitive to venom experience intensive burning, followed by swelling and itching at the sting site. Treatment consists of application of analgesic gel or ice to relieve pain and reduce swelling. Household meat tenderizer is sometimes used to degrade venom proteins.

Approximately 0.4-0.8% of the human population is sensitive to wasp venom. When these individuals are stung, reactions can range from itching and burning at the site of the sting (the common reaction of non-sensitive individuals), through several intermediate stages, ultimately to coma and death. Delayed reactions in sensitive individuals may occur up to 96 hours after the sting occurred. (See Akre et al. 1981, and Frazier 1976, for details). Anyone exhibiting symptoms of sensitivity, or with a history of reaction to stings, should be transported to the nearest medical facility as soon as possible. If qualified, park personnel may begin emergency treatment if necessary.

8.2 Indirect Effects:

The major indirect effect of yellowjackets is the fear of being stung, particularly when flying yellowjackets are common. Anxiety and nuisance have resulted in auto accidents, lost work, and lessened enjoyment of the outdoors by park visitors.

8.3 Sting Therapy:

Immediately following the sting, intense burning is experienced at the site of the sting, followed after several minutes by swelling and intense itching. The swelling may be localized to a few centimeters immediately surrounding the sting, or may involve an entire extremity or other part of the body.

Ice or cold compresses on the sting site relieve burning and itching. Applying a meat tenderizer containing papain will also relieve some symptoms. (The enzyme in meat tenderizer breaks down proteins which are the major components of venom). Antihistimines may be administered as well in more severe cases.

Symptoms of a generalized systemic reaction may range from mild to severe. Frazier (1976) stated, "Such reactions can be delayed, presenting serum sickness-like symptoms of fever, headache, malaise, rash, lymphadenopathy, and polyarthritis. It is an immediate reaction, however, that presents the physician with a medical emergency. Even a slight systemic reaction with symptoms of generalized rash, itching, malaise, and anxiety should be assessed and treated on a long-term basis in the realization that the next time the patient is stung the results may be far more serious, even life-threatening.

"A moderate systemic reaction may be marked by any of the symptoms mentioned above and two or more of the followings: (1) constriction of throat or chest; (2) abdominal pain, nausea, vomiting; (3) dizziness; (4) wheezing; and (5) generalized edema.

"A severe systemic reaction may include any of the above symptoms and two or more of the following: (1) labored breathing; (2) difficulty in swallowing, hoarseness, or thickened speech; (3) weakness; (4) confusion; and (5) a feeling of impending disaster.

"A shock or anaphylactic reaction would include any of the above symptoms in addition to two or more of the following: (1) lowered blood pressure; (2) cyanosis; (3) collapse; and (4) unconsciousness."

In severe reactions, subcutaneous injection of epinephrine (1:1000) at .02-.05 ml dosage is prescribed (maximum 0.03 for children). Injections should only be administered by a physician or qualified emergency medical technician. Any park which does not have access to a hospital should have qualified Emergency Medical Technicians (EMTs) on staff. Contact your park or regional health and saftey officer for further information.

Kits are available by prescription which contain a preloaded syringe of epinepherine, antihistamine tablets, phenobarbital tablets and directions for use.

9. **Natural enemies:** Yellowjackets are preyed upon by birds and some mammals(especially skunks which may dig up and consume several nests in a single night). A parasitic wasp invades colonies, laying its eggs on and destroying yellowjacket larvae. Yellowjackets are also sometimes affected by nematodes and pathogens which destroy brood and workers.

III. YELLOWJACKET MANAGEMENT

1. Population Monitoring:

The objective of an IPM program for yellowjackets is not eradication, but separating yellowjacket and human populations to minimize interaction (i.e. stings). Therefore, pest yellowjackets are monitored in specific areas of human activity rather than on an area wide basis. Trails, picnic areas and trash cans are some of the areas which should by monitored. See Giraldi and Hackett (1982) for specific techniques for monitoring in special circumstances.

Monitoring trails and picnic areas consists of visual inspections for flying yellowjackets and nests. Trash, especially soft drink or beer containers, will attract foragers late in the season.

Trash cans are monitored by counting the number of visiting foragers in a 10-minute period, several times a day, on a daily basis late in the season.

Stings should be recorded either on standard NPS Case Incident Record Forms, or the sting form on page 19. The sting form is usually better because more detailed information can be provided. Recording sting information provides data on where in the park the most stings occur and where special efforts should be made in implimenting the IPM program. Data from the sting form will also indicate what sort of problem exists (e.g., a single sting received on the foot while walking barefoot in a grassy area is probably due to a bee, while stings on the hands or face while eating are due to yellowjackets). Multiple stings on the legs or ankles usually indicate that the victim has disturbed a ground nest. First aid is also recorded; a copy may be made for the victim to take to their doctor. Sting data also provide an evaluation of the success of the IPM program.

2. Threshold/Action Population Levels:

Threshold levels and action populations will vary from park to park, as well as throughout the season. A park which has several incidents of stings each season may be more (or perhaps less) tolerant of high yellowjacket populations than a park in which only a few stings are reported. Any area which has had a death or near death occur from stings will also have a lower tolerance threshold to yellowjacket numbers.

As the season progresses and yellowjacket numbers increase, tolerance will proportionaly decrease.

Wagner (1961), has determined that 15 foragers visiting an open garbage can in 10 minutes is indicative of a severe yellowjacket problem.

If, for example, stings increase when counts of foragers visiting garbage containers are 10 yellowjackets in 10 minutes, you may wish to set action levels at 5 yellowjackets in 10 minutes. Action might include more frequent garbage pickup, washing cans, or using insecticides in cans (see sections III.3., and III.4.). Good record keeping and sampling will enable you to eventually correlate stings with numbers of foragers and set treatment levels which are unique for your park.

3. Management Alternatives - Nonchemical:

The basis for non-chemical management is to separate human and yellowjacket populations in order to reduce contact between them.

1. Public education - Displays, handouts and other information should be presented to inform the park visitor that wasp stings are mostly avoidable if a few precautions are followed. Educational materials should emphasize the place wasps have in the overall park environment. See the sample education flier, page XLVI-23.

2. Refuse management - All refuse containers should be solid "tulip type" (no wire mesh) plastic or metal containers and equipped with wasp-tight lids to prevent foragers from gaining access to the interiors. All containers should be checked regularly for gaps and holes. Refuse should be collected on a regular basis before containers are full. This may entail collection several times a day, particularly in picnic areas and during period of heavy park use, such as weekends. Containers should be cleaned or washed regularly to reduce attractive odors.

3. Concessions cooperation - All beverages sold by concessions in the park should be supplied with plastic lids on cups and straws. This prevents foraging wasps from crawling into the cups as well as reducing their attractiveness (odor) to foragers. In addition, spillage is reduced when the cups are discarded by the visitor.

In one Eastern park where these simple management steps were taken, the number of stings dropped from 57 in one year to 2 the following year, a reduction of over 95% (see Giraldi and Hackett, 1982).

4. Trapping - Traps can temporarily reduce the number of foragers in an area. It should be noted however that an individual colony can have up to 5000 workers in normal circumstances (in tropical or subtropical regions, one periennial colony may contain over 1 million workers), so trapping at best affords only temporary relief in limited areas.

   Funnel traps using synthetic lures (such as heptyl butyrate) have been used successfully to capture western yellowjackets, reducing local densities to tolerable levels for short periods (Davis et al ,1973). Lures have not yet been proven useful against eastern species but research is continuing (Howell et al 1974). A problem with synthetic lures is their attractiveness to beneficial yellowjackets. While these lures may attract large numbers of insects, the percentage of pest species may be small.

   Temporary control of V. pensylvanica has been achieved (Akre, et. al.,1982) using traps consisting of raw fish (with the flesh exposed by cutting or breaking the skin) suspended above pans containing water and a wetting agent (to reduce surface tension). Yellowjackets visiting these traps typically cut large pieces of flesh from the hanging carcass, and attempted to carry them to sites where they can be trimmed to manageable sizes. The initial pieces were generally so large that the insects fell with them into the water and drowned.

   Advantages of the fish trap include ease of construction, effectiveness, and lack of toxicity. Disadvantages include the need to change the bait often (yellowjackets do not scavange spoiled flesh), and the attractiveness of the bait to dogs, cats, and wildlife; chickenwire cages can be placed around traps to provent damage by large animals. In a 1973 test (Akre et. al.,1982), 9 traps set up in a resort area captured nearly 1000 foraging workers per week. Trapping and improved garbage management reduced the number of active foragers in the area to tolerable levels within two weeks.

5. Biological control - Biological controls against yellowjackets do not yet exist. Naturally occuring parasites and predators have little or no effect on colony dynamics. Destruction of overwintering queens attempted in New Zealand and Cyprus, showed no effect on populations the next spring (Akre et. al.,1982). Yellowjacket colonies produce large numbers of queens, most of whom do not survive to found new colonies. It has been estimated (Spradbury, 1973) that natural mortality of new queens and new colonies approaches 99.9%. Destruction of queens in winter may actually increase the number of successful colonies by reducing queen competition for suitable nesting sites in spring. Poinar and Ennik, (1972) used parasitic nematodes for yellowjacket reduction with some success experimentally. In the wild, conditions within the colony make survival and dispersal of nematodes difficult at best. Few positive data exist for field trials.

6. Mechanical control - In situations where chemicals cannot be used for underground nest destruction, 2 workers (in bee suits, using a cannister type vacuum cleaner) can excavate and destroy a colony in a few minutes. Vacuuming destroys workers, comb, and brood. Vacuum bags are plugged and frozen to kill the contents.

   All nonchemical control measures (especially garbage management, lids on refuse cans, and lids on soft drinks) should be in place before yellowjackets become abundant late in the season. Yellowjacket foragers return to the same food source many times, and cutting off food sources late in the season may result in large numbers of aggressive workers flying around trash cans.

4. Management Alternatives-Chemical:

Due to the large numbers of colonies and workers usually found in most areas, area wide chemical control of foragers is impractical, if not impossible. However, individual colonies, in hazardous locations can be destroyed by chemical means. Nest destruction should be only attempted after dark when most of the foragers are in the nest and activity has ceased.

Anyone attempting to destroy a subterranean or structural nest should wear a bee suit and take further precautions against stings.

1. Underground nests - Subterranean colonies can be destroyed by pouring insecticides into the entrance, which is then plugged with cotton or steel wool. The plug and surrounding area should be treated to destroy returning foragers which have spent the night outside the colony. Aerosols containing pyrethins, rotenone, and a cooling agent (Wasp-Freeze®) to lower activity may also be used; see Akre et al (1982). Use of gasoline for nest destruction is not recommended.

2. Aerial nests - Several products are sold for aerial nest destruction. These contain a cooling agent or a pesticide which provides rapid knockdown. Aerial nests should only be destroyed at night.

3. Nests in structures - Yellowjackets nesting in walls are difficult to control, but success has been reported by researchers using pyrethroids blown into the entrance hole, which is then plugged with steel wool treated with 1 oz. of 5% carbaryl dust. Yellowjackets trying to escape, as well as returning foragers contact the material and die. Structural nests may be destroyed by this method during daylight hours. See Nixon (1982), for details.

In colonies not treated (i.e.: healthy colonies), the entrance hole should not be plugged. If the hole is plugged, a heathy colony will chew a new hole through the wall, and emerge into living spaces. See Akre, et al (1980), and Nixon, (1982).

Insect growth regulators (IGRs) such as methoprene have been tested against the eastern yellowjacket and German yellowjacket with some success (Parrish & Roberts 1983). Still experimental, this method shows promise for future application.

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

5. Summary of Management Recommendations:

1. Plan for emergency care of sting victims who are sensitive to venom. Have first-aid facilities for nonsensitive victims. Monitor stings.
2. Establish garbage management programs inclucing wasp-tight covers on all refuse containers, and regular and frequent pick-up and removal. Wash containers if necessary. Monitor containers for visiting foragers.
3. Provide lids and straws on all soft drink containers sold by concessions; provide public education material on yellowjackets and wasps.
4. Destroy structural nests, ground nests, and aerial nests chemically if necessary.

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STING MONITORING FORM

Date:________________________ Filed By:__________________________

1. Where in the park did the sting occur?

2. What was the victim doing when stung?
(example: walking on trail, throwing away trash, sitting at table, etc.)

3. How many times was the victim stung?

4. Location of sting(s) on victim's body:

5. What was the reaction to the sting(s)?
(example: pain and redness, swelling in area of sting, swelling of limbs, nausea, respiratory distress, other)

6. What was follow-up treatment?
(example: application of gel, ice, referral to doctor, etc.)

7. Did victim receive printed materials on stings?

Yellowjacket Monitoring Form

Map

Date:_________ Map Reference #:_____________ Recorder:__________________
Weather/Temperature:____
Park Location:____
Park Use: picnic area, path, recreation area, forested area, other____________
Yellowjacket/wasp species observed and their behavior:_________________________

Food and waste management practices:

1. Are concessions providing lids and straws for beverage containers? y n
2. Are garbage containers wasp-tight? y n
3. Are garbage cans overflowing because garbage is not collected frequently? y n
4. Are there enough garbage cans? y n
5. Are spills cleaned up or hosed down? y n

Counts of yellowjackets visiting a garbage can in 15 minutes:
(Identify the can on the map)
Presence of active nests:
Where: (identify on the map)

Treatments:

Comments/Recommendations:

COUNTS OF YELLOWJACKETS VISITING GARBAGE CONTAINERS

Park:

Recorder

Date:

Time of Day:

Weather/temperature (sunny, stormy, etc.):

Where can is located*:

Number of yellowjackets observed visiting the can in 15 min.

Yellowjacket species observed:

*An alternative to this form is to draw the park location where garbage containers are to be monitored. This picture will help prevent confusion as to which container was monitored. Monitoring data can be placed right on the form.

YELLOWJACKET STING SHEET

Yellowjackets are small colonial wasps which normally nest in the ground. In late summer, colonies are at maximum size. Workers are common in picnic areas and around trash cans where they hunt for sweets. Yellowjackets sting readily and a worker may deliver more than one sting.

YELLOWJACKETS ARE ATTRACTED TO:

1. Perfumes and other scents
2. Hairspray
3. Suntan lotion
4. Cosmetics
5. Brightly colored clothes
6. Sweets

WAYS TO DECREASE STINGS:

1. Don't go barefoot
2. Don't swat with your hands
3. Avoid using things yellowjackets are attracted to
4. Use lids on soft drink cups
5. Put tight fitting swing type lids on trash cans
6. Have frequent trash can pick up

STINGS

In most people, a yellowjacket sting produces an immediate pain at the site of the sting. There will be localized reddening, swelling, and itching. Ice or analgesic creams often relieve the symptoms.

IF YOU ARE STUNG:

1. Remove the stinger by scraping from the side (for bees)
2. Apply cold water or ice in a wet cloth
3. Lie down
4. Lower the stung arm or leg
5. Do not take alcohol

Some people experience an allergic reaction to yellowjacket venom. Allergic (anaphylactic) shock can be fatal if untreated. Symptoms usually occur 10-20 minutes after a sting but may appear up to 20 hours later. If you experience any of the following symptoms after being stung, obtain medical aid immediately:

SYMPTOMS OF ALLERGIC REACTIONS:

1. Hives
2. Wide-spread swelling of limb
3. Painful joints
4. Wheezing
5. Faintness
6. Dizziness
7. Vomiting
8. Abdominal cramps
9. Diarrhea
10. Shortness of breath
11. Nasal discharge or stuffiness
12. Tightening of throat

WHAT TO DO:

1. Lie down; victim should not be moved
2. Lower the stung arm or leg
3. Apply ice
4. Do not take alcohol
5. Apply rubber bands or wide cloth above the sting between sting and heart (should be able to place 2 fingers under bands); remove after 5 minutes
6. GET MEDICAL AID

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