INTEGRATED PEST MANAGEMENT FOR PARK MANAGERS

A Training Manual

by

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DISCLAIMER

CONTENTS

PART TWO: MAKING THE TRANSITION TO IPM

FIGURES, TABLES AND SAMPLE FORMS

FIGURES

TABLES

SAMPLE FORMS

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Part One

Understanding the IPM Approach

WHAT IS IPM?

DEFINITIONS

Integrated pest management (IPM) is the selection, integration, and implementation of pest control based on predicted economic, ecological, and sociological consequences.

IPM seeks maximum use of naturally occurring pest controls, including weather, disease agents, predators, and parasites. In addition, IPM utilizes various biological, physical, and chemical control and habitat modification techniques. Artificial controls are imposed only as required to keep a pest from surpassing intolerable population levels predetermined from accurate assessments of the pest damage potential and the ecological, sociological, and economic costs of the control measures.....

(Since IPM was originally developed in agricultural settings), major emphasis has been placed on cotton, citrus, deciduous fruits, soybeans, and alfalfa, which account for approximately 70 percent of the insecticides applied annually to cropland....For nearly every crop included in (Cooperative Extension Service) demonstrations in over 30 states, pesticide use has dropped significantly without a sacrifice in yield or quality and with increased profit to the farmer.

Equally encouraging results have been achieved in IPM programs directed against pests affecting urban areas, public health, and forests. (Dale Bottrell, Council on Environmental Quality, Integrated Pest Management. 1979. Emphasis added.)

A Short Definition

Integrated pest management (IPM) is a decision-making process. It helps you to decide:

- If treatment action is needed
- Where treatment activity should take place in the system
- When action should take place
- Which mix of strategies and tactics would be the best to use

The components of an IPM program are:

- Monitoring
- Determining injury and action levels
- Timing
- Defining problem area
- Selection of least disruptive tactics
- Spot treatment
- Evaluation

Applying the IPM Concept

The major components of an IPM program remain the same, no matter what the target pest. The first and most important component is the development and operation of a monitoring program. A monitoring program is essential in order to determine injury and action levels, define problem area, select and time treatments that are least disruptive to the natural controls operating to suppress the pest organisms and least hazardous to human health and the environment, and evaluate the pest management program as it proceeds. Monitoring is an on-going activity throughout any IPM program.

Monitoring: The Key to IPM

The purpose of monitoring is to gather and record site-specific information on which decisions about treatment choices are to be based. Monitoring provides managers with: baseline data, ways to compare one season with another, tools for measuring progress and determining true costs, and reference points for all pest control decisions.

MONITORING: THE BASIC ELEMENTS

Monitoring means regular inspection.

Monitoring may require special tools (e.g. hand lens, ladder, flashlight, trap) to answer the questions:

- What kind of pest problem?
- When and where does the problem occur?
- How many--what is the extent of the pest population or the problem?
- When should treatment action take place?

Monitoring requires record keeping

WHAT SHOULD YOU LOOK FOR?

1. The target pest--what species is it; how many; where does it occur geographically, seasonally, in the micro environment?

2. The natural enemies of the pest--what kind; how many; where?

3. Potential pests that could cause secondary problems--what kind; how many; where?

4. Maintenance activities that may affect the pest--what are people doing regularly? For example, how plants are watered, pruned, and fertilized can affect landscape pest problems. How food is stored and wastes managed can affect indoor problems.

5. Random human and other events--the unanticipated that may affect the pest.

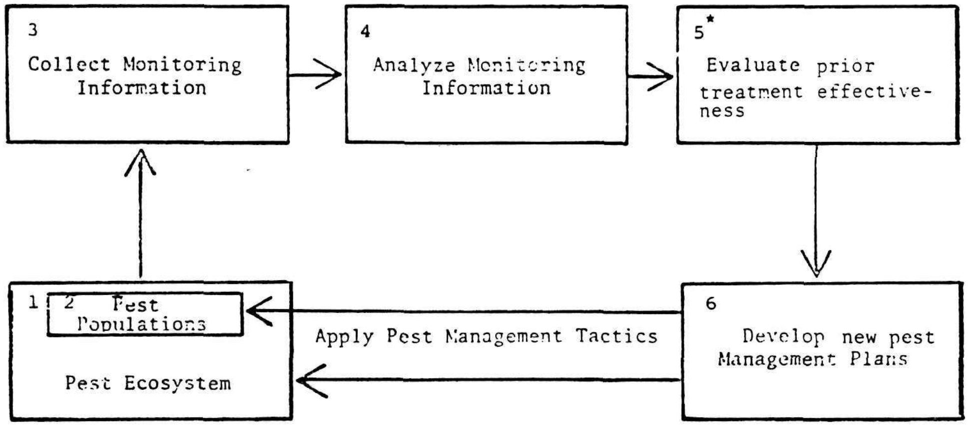
6. Weather--how hot, cold, wet, dry, windy? How long? Local variations?

LEVELS OF EFFORT USED IN MONITORING

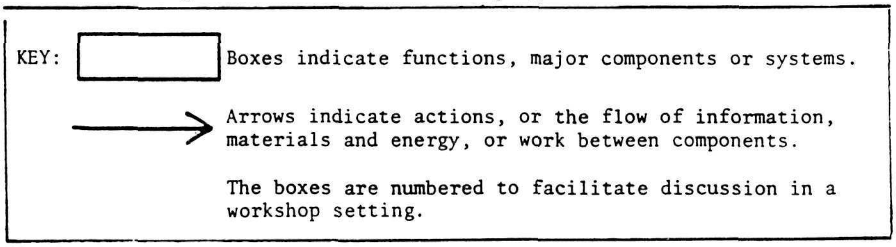
1. Other persons casual looking (= hearsay).
2. Casual looking with no record keeping.
3. Casual looking with written observations.
4. Regular written observations.
5. Regular written observations and quantitative descriptions.
6. Quantitative samples on a regular basis.
7. Statistically valid quantitative samples.

Note that in the above there is a progression from the least (#1) to the most intensive. Reliability and precision also follow this same progression.

FIGURE 1
THE ROLE OF MONITORING



*Treatment being evaluated refers to pest suppression activities either prior to or following the initiation of an IPM program.



RECORD KEEPING

A monitoring system is only as useful as its record keeping system. Records are the memory of the system. Without records, whatever is learned is lost when personnel are changed, and consequently no learning takes place except that which is transmitted verbally. Verbal transmission alone is prone to error and is seldom verified by quantifiable observations. Records form the basis for making decisions on the most sensible distribution of available resources to the areas most in need of attention or observation.

WHAT SHOULD THE RECORD SHOW?

- Identification of the pest: genus, species, stage, etc.
- Size of pest problem
- Distribution of pest problem
- Information on treatment action: what, where, when, who, cost, application difficulties
- Short-term effects on pest problems
- Short-term effects on non-target species
- Long-term effects on pest problems and non-target species

It is important to standardize both the format and the process by which the records are kept. This will aid in achieving continuity.

WHAT CAN BE LEARNED FROM MONITORING?

INJURY AND ACTION LEVELS

Determining Injury Levels

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 injury for a specific site. Two values comprise an injury level. The first is the amount of aesthetic or economic damage that can be tolerated. The second is the population size of the pest that must be present to cause that much aesthetic or economic damage.

Setting an injury level may be fairly clear-cut in an agricultural context in which these concepts were developed. For crop production systems, the question of injury level is: How much reduction in yield, or cosmetic damage to the product, can occur before the loss of profits is equal to or greater than the probable cost of pest control? In other words, how much pest damage will make pest management economically worthwhile?

In ornamental landscapes, however, and in buildings, the direct economic damage is often difficult to assess. In such cases, injury or damage are a matter of aesthetic judgment or peoples' opinions. Peoples' opinions differ, and the realities of social systems are that not all opinion carries equal weight in determining policy. Thus, in cases of aesthetic damage, the question may become: How much are the "important" people willing to tolerate of:

- change in appearance of the plant or site (including loss of host)
- visibility of the pest
- evidence of pest activities
- nuisance

Treatments are usually based on some notion (usually unspoken) of injury level. Managers frequently act on injury level concepts they have inherited from previous managers or casually accepted along with others in the system. For the decision-making process to yield effective work orders, however, the injury level should be redetermined at frequent intervals for each pest and for each site.

On What does Injury Level Depend?

A. Potential for damage

- Pest species/host species. It is important to identify the pest and host. All aphids are not alike, nor are all weeds. All species and cultivars are not equally susceptible to the same pest.

  Example: the tuliptree (*Liriodendron tulipfera*) can tolerate large numbers of tuliptree aphids (*Illinoia liriodendri*), but a small population of the spruce aphid (*Elatobium abietinum*) can kill a spruce tree (*Picea* sp.).

- Pest population size causing intolerable aesthetic, medical or economic damage.

  Example: the damage caused by one leaf-eating beetle in the tree will not even be noticed. Five thousand of them may cause highly visible defoliation.

B. Tolerance of the clientele

- Location.

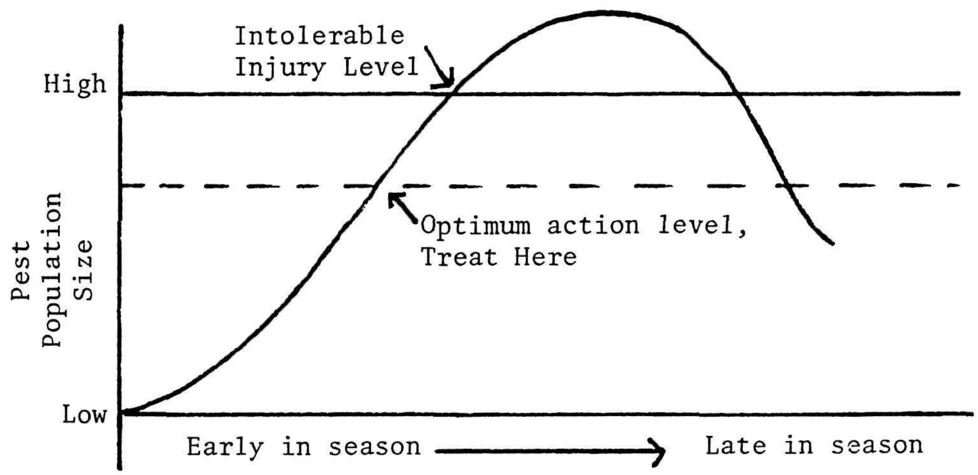
  Example: rose plants by a walkway are highly visible individually. Thus even a low level of damage will be noticed. But, massed in a border and seen only from a distance, they can easily sustain much greater insect activity without affecting the overall aesthetic appearance of the display. In most cases, specimen plants would receive greater attention than individual plants in a mass planting.

Determining Action Levels

The purpose of setting injury levels is to guide pest management actions. Action levels are determined in relation to injury levels. An action level is the level of pest population size for a specific site at which action must be taken to prevent reaching the injury level. See Figure 2.

FIGURE 2

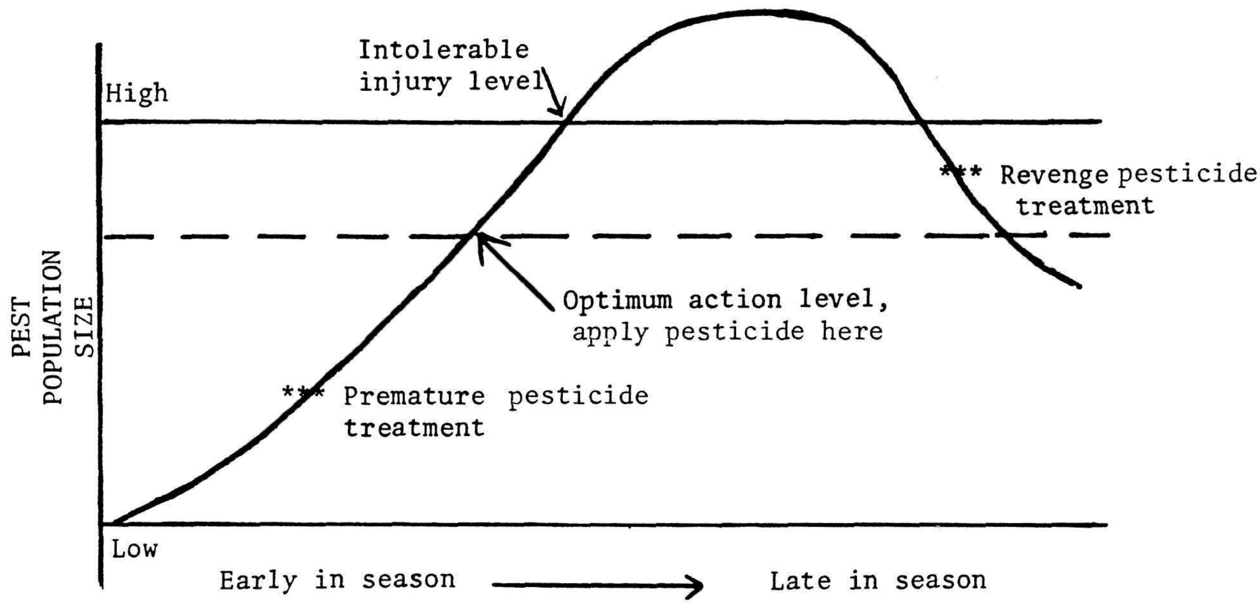
INJURY AND ACTION LEVEL CONCEPTS



In situations where treatment means application of a pesticide, action often takes place long before it can be predicted that the injury level will be reached. These are sometimes thought of as "preventive treatments," often applied on a calendar basis, but in reality are premature and probably trigger more pest problems than they prevent. Sometimes action takes place after the injury level has been reached and the pest population has begun to decline naturally. Such "revenge" treatments are useless (at best), wasteful, and may trigger new problems (at worst). See Figure 3.

FIGURE 3

INJURY AND ACTION LEVEL CONCEPTS
SHOWING PREMATURE AND REVENGE PESTICIDE TREATMENTS



TIMING TREATMENTS

Monitoring can help time treatment actions properly in the life cycle of the pest and of its natural enemies.

Example 1: When the scale crawlers move out across the plant is when they are most vulnerable to soap and water washes or contact insecticides.

Example 2: The microbial insecticide B.t. (Bacillus thuringiensis) is a stomach poison, thus it will not work if sprayed when moths are flying since they do not feed. It must be used when the caterpillars are actively feeding.

Example 3: When predatory ladybeetles are in the pupal stage they are less vulnerable to certain sprays than as larvae out on the leaves.

Example 4: Bagworms are more susceptible to B.t. before they have constructed their bags.

SPOT TREATMENT

There may be a substantial difference in the degree to which different species in the same genus respond to pest attack. Furthermore, in every group of plants of the same species and variety there are individual variations. Ideally only those individual plants on which pest populations are approaching injury level should be considered for treatment.

Example 1: Where a leaf-eating insect crawls down to the base of the tree during each generation, a narrow band of insecticide applied to the trunk may be less costly and much safer than spraying the entire foliage. Confining the poison to a band on the trunk also protects the natural enemies of the pest on the leaves and on the ground. (Ex. elm leaf beetle.)

Example 2: Elms on two neighboring streets in Modesto, California were originally treated routinely for elm leaf beetle, although only certain trees required it. Other trees showed no damage without treatment. Monitoring pinpointed which trees were regularly susceptible and which were not.

TREATMENT STRATEGIES

A strategy is an overall approach to a problem, such as using "habitat management" to suppress a pest. A tactic is a specific action or series of actions within that strategy. For example, draining water from a depression is a tactic that might be part of the strategy of habitat management for mosquitos.

CRITERIA FOR SELECTING TREATMENT TACTICS AND DEVELOPING PEST MANAGEMENT STRATEGIES

Once the IPM decision-making process is in place and the decision made to use a pest suppressive tactic, the choice of actual strategy and technique can be made. Choose strategies that are:

- least disruptive of natural controls
- least hazardous to human health
- least toxic to non-target organisms
- least damaging to the general environment
- most likely to produce permanent reduction in the pest
- easiest to carry out effectively
- most cost effective in short and long term

SUMMARY OF TREATMENT OPTIONS AVAILABLE

A pest management strategy is a group of planned tactics or methods for preventing or suppressing pest populations based on ecological understanding. The IPM concept is based on the fact that combined strategies for pest management are more effective in the long run than a single strategy. The major strategies to be considered are:

I. Indirect suppression

   A. Design or redesign of the landscape or structure. This includes:

      1. Selection of plants or structural materials that are:
         - resistant to pests
         - supportive of natural controls
         - enhancing of ecosystem diversity and processes

2. Landscape or structural designs that are:

- conducive to plant health or sound structure maintenance
- appropriate to the weather, soils, minerals, water and energy resources of the site and the maintenance system

B. Habitat modification or changing the biophysical environment for purposes of:

1. Reduction of pest harborage, food, or other requirements.
2. Enhancement of the environment required by the pest's predators, parasites, and diseases.

C. Human behavior changes, including:

1. Horticultural controls
   - modification of such resource management practices as mowing, cultivating, watering, fertilizing, pruning, mulching, and waste management
2. Education
   - modification of aesthetic judgments regarding "cosmetic damage," manicuring of landscapes, and visual presence of certain animal species
   - using an ecosystem approach

II. Direct Suppression

D. Physical controls such as:

1. Manual picking, weeding, etc.
2. Barriers
3. Traps
4. Mechanical action
5. Heat or cold
6. Caulking

E. Biological controls, including

1. Conservation of the pest's natural enemies through proper selection of materials and timing and placing of treatments.
2. Augmentation through the introduction of additional numbers of the pest's natural enemies or commercially available pathogens.
3. Inoculation by the repeated reintroduction of effective natural enemies that will not survive over winter.
4. Importation of host-specific natural enemies of exotic invaded pests.

F. Chemical controls, including:

1. Pheromones and other attractants to lure and/or confuse the pest
2. Juvenile hormones that arrest pest development
3. Sterilants or contraceptives to reduce breeding of future generations
4. Contact, stomach, and other poisons
5. Fumigants

EXAMPLES OF TREATMENT OPTIONS

Note: In these examples, the strategy described was only one of the several used in combination to solve the pest problem.

1. Design or Redesign--the purpose of this strategy is to design the pest out of the system through the choice or arrangement of either plant or structural materials.

   Example: A stable fly problem in a park police horse stable: The stable flies lay their eggs in the manure. Site examination disclosed that stable design included construction with individual boards with spaces between. These gaps permitted manure to fall through and accumulate in areas inaccessible to regular cleaning. Recommendation: switch to solid wall construction of stalls, i.e. change the design.

   Example: Azalea lace bug problem on azaleas which are more severe in exposed areas. Often azaleas are planted in full sun even though under natural circumstances they are understory plants. Recommendation: add taller plants, lath, sunshade, etc. to provide filtered sunlight or substitute sun-loving plants, i.e. change the landscape design.

2. Habitat Modification--the purpose of this strategy is to change the biophysical environment so as to reduce the carrying capacity for the pest, i.e. the potential of the environment for supporting a large pest population. Sometimes this may be done by enhancing the attractivensss of the site to the natural enemies of the pests.

   Example: Solving mosquito problems usually includes finding the water sources where the young mosquitos are developing and either draining some of them or raising the water level in them so that a particular nuisance mosquito will no longer lay its eggs there.

Example: Artificial perches, in the form of posts, may be introduced into a grassland area to encourage the presence of predatory birds such as red-tailed hawks that feed on pest ground squirrel populations. Nest boxes may be introduced into forest areas to encourage presence of insect-eating birds.

3. Human behavior changes, including:

Horticultural controls--horticultural controls involve modifying planting and maintenance activities to affect pest populations. These activities include:

- plant selection
- planting techniques
- watering
- fertilizing
- pruning
- mulching

Example: Honeydew drip problem with ash trees: ash aphids may favor the inner canopy of certain varieties of Ash trees. By thinning out the interior of the tree and using pruning techniques that do not encourage sucker growth, the favored habitat of this pest can be reduced.

Example: A citizen group is pressuring for reduction of herbicide use on turf weed problems. Mulching with compost to reduce compaction in areas of visitor traffic and selection of more appropriate grass species or alternative ground covers may reduce weed problems in some areas.

Education—education is usually a cost-effective strategy. Tolerance for certain organisms and a general understanding of the benefits of taking an ecosystem approach can be increased by education.

Who needs to receive information?

1) Pest control professionals
2) Landscape and building maintenance personnel
3) The general public
4) Policymakers in public and private institutions and agencies
5) Landscape and building designers

What do they need to know?

1) To look at the whole picture, that is, to take an ecosystem approach: include physical, biological, psychological, sociological and economic factors.

2) Look for alternatives first and use pesticides only as a last resort.

Examples: Weed (wild plant) problems in turf and labor shortage might be solved by turning certain park areas into meadows by mowing less frequently per season. Education will be required so that visitors understand the effect achieved is deliberate. Visitors should be taught to appreciate the changing panorama of wildflowers as the season progresses and the role of these wildflowers in feeding beneficial wildlife.

4. Physical Controls--physical controls involve using physical methods to destroy or exclude the pest.

Examples include:

Handpicking: Removing tent caterpillars or fall webworms with a pole pruner or hand clippers.

Vacuuming: Yellow jacket nests out of the ground; box elder bugs as they collect around building foundations.

Traps: For flies, whiteflies, rodents, Japanese beetles, other pests.

Barriers: Against flying insects (screens), birds, (netting), pantry pests (storage in tight jars), rodents (garbage storage containers, e.g. modifying park garbage cans to include tight lids with spring closing deposit doors, metal bottoms, and stands to raise them off the ground will provide a barrier against rats, yellow jackets, dogs, raccoons, etc.).

5. Biological Controls--biological control involves maximizing the impact of the pest's natural enemies, i.e. predators, parasitoids, and pathogens. Examples include well-recognized pradators such as toads, snakes, hawks and ladybird beetles, and less well-recognized internal and external parasitoids of insects such as predators of aphids, scales, beetles and caterpillars. Types of biological control include:

A. Conservation of biological controls--that is, protect those already present in your environment.

- treat only if injury levels will be exceeded
- spot treat to reduce impact on the natural enemies of the pest
- time treatments to be least disruptive
- select most species specific, least damaging materials

B. Augmentation--artificially increase the numbers of specific biological controls normally already present in low numbers. For example, brown-banded cockroaches have been controlled indoors through releases of large numbers of their parasitoid. Some examples of commercially available predators and pathogens include lacewings, predatory mites, insect diseases such as *Bacillus thuringiensis israelensis* effective against mosquitos and black flies.

C. Inoculation--releasing natural enemies at the beginning of the season which are not normally present but which will not permanently colonize. One example is the control of the Mexican bean beetle by a parasite, *Pediobius faveolatus*, reared and released in large numbers by the USDA.

D. Importation--importing and permanently establishing the natural enemies of an invaded pest.

- host specificity is the key consideration
- permits must be obtained from the Federal government (APHIS) and the material sent through a USDA-supervised quarantine laboratory which observes a strict protocol
- weeds, both terrestrial and aquatic, as well as insects, have been suppressed through biological control importation. Examples are cottony cushion scale, a major pest of citrus, controlled in California in 1888, and ongoing control of tansy ragwort by the cinnabar moth in the Northwestern United States
- if a biological control importation project is successful, the pest population will be reduced to tolerable levels over a period of seasons. Patience is needed because the process may be slow, but it is permanent
- this work is done by highly specialized personnel in approved laboratories

6. Chemical controls--chemical controls have a place in an integrated control program, and when used, should be applied in carefully timed applications.

   Choose materials that are:

   - least acutely toxic to the operator
   - least chronically toxic to the operator
   - most species specific
   - most effective
   - easiest to apply
   - most cost effective

   A wide variety of chemical controls are commercially available:

   - attractants (e.g. pheromones)
   - repellants
   - hormones
   - sterilants
   - poisons (e.g. fumigants, stomach, contact, systemics
   - a combination (e.g. baits or traps using attractants and poisons)

HOW TO SELECT A PESTICIDE FOR AN IPM PROGRAM

First consideration in choosing a strategy should always be given to those that are permanent (design change, habitat modification) or non-toxic (horticultural, physical and biological controls, and education).

If you select a pesticide be aware that they:

1. Are powerful in their direct and indirect effects upon ecological systems and individual species, particularly humans.
2. May produce new problems in the target pest population, including
   - resistance of the pest to the material so it is ineffective in emergency situations
   - target pest resurgence through reduction of natural enemy populations
   - secondary pest problems by accidentally killing natural enemy populations of non-target organisms

3. Are increasingly expensive
4. Are not permanent
5. Carry special legal liability
6. If used when alternatives are available may create public relations problems

The following criteria are presented for use when selection of any suppressive strategy is made, particularly (but not limited to) synthetic, chemical tools, including plant-derived compounds:

- Effectiveness
- Selectivity
- Operator safety
- Environmental Persistence
- Resistance

Effectiveness

The judgment concerning effectiveness should ideally be based on information from controlled studies conducted by objective persons or agencies. Actual inspection of the results of such studies is important since registration alone (i.e. existence of a label) is no guarantee that the product will work in your area under your circumstances at all times. Before widespread use of any material, a pilot study should be conducted to indicate the utility of the material and procedure under the desired circumstances.

Selectivity

The material in question should be evaluated as to its effects on natural enemy populations (predators, parasites and pathogens). Those materials with known detrimental effects on natural enemy populations should be avoided. This will prevent development of target pest resurgence and secondary pest problems that require additional treatments.

Operator Safety

When choices are available, those materials that could produce adverse effects if misused or if accidentally released into the environment should be avoided. Higher LD_{50} numbers* indicate less immediate hazard than the lower numbers. However, LD_{50}s should not be the only method used to select one material over another because they do not take into account potential long-term exposure hazards. At present the only way the mutagenic, carcinogenic and teratogenic (causing birth defects) potential of a material can be assessed is to use animal test data together with epidemiological studies of exposed populations (such as certain occupational groups). Even after LD_{50} and other studies indicate a material to be hazardous in laboratory conditions, the evaluation needs to consider the actual equipment and procedures to be used under typical conditions.

*Note: LD_{50} is a rating of the acute toxicity of a material. It refers to the lethal dose (either oral or dermal) per kilogram of body weight required to kill 50% of the test animals (usually mice, rats or rabbits).

Environmental Persistence

Those materials shown to have long-term potential to persist in the environment (half life of weeks, months or years) should be avoided. Shorter-lived materials are usually preferable. The rationale behind this criterion is that longer-term persistence of a particular chemical or chemical group indicates greater environmental impact because longer persistence increases the potential for exposure through unforeseen routes. This criterion should also be applied to the breakdown products of known active ingredients, some of which are more toxic than the original material. (Example: Mirex breaks down into Kepone, DDT breaks down into DDE.)

Resistance

If somewhere in its geographical range the pest is known to be resistant to a material, that material should be avoided if possible. If no feasible alternatives are available, resistance testing should be conducted in the local area and, ideally, monitored over time to detect resistance when it first appears. Signs of resistance can frequently be detected by inspecting field records of application frequency and dosage. When frequency or dosage increases, resistance may be indicated.

RECORDS DESIRABLE WHEN PESTICIDES ARE USED

1. Pesticide purchases: trade name, source, cost, dates of purchase.
2. Pesticide storage: what material (by trade and generic names), storage location, length of storage, container condition, amount stored (total/active ingredient), method of access, personnel access.
3. Records on pesticide use:

   a. location
   b. date
   c. applicator
   c. trade name
   e. active ingredient
   f. EPA Reg. No.
   g. pest
   h. amount of product
   i. area treated
   j. amount 100% active ingredient

   See Pesticide Use Log (Sample Form 1). Also see the discussion of this subject in Part II (pages 71-76).
4. Pesticide disposal: what material (by trade and generic names), where and when disposal occurred, method of disposal, responsibility for disposal site, how was material transported to the site.
5. Health records:

   a. Routine health and work records, e.g. number of days lost, cause, treatments

Sample Form 1

SAMPLE SAMPLE SAMPLE SAMPLE SAMPLE

PESTICIDE USE LOG

PARK : *Green Prairie National Park*
REGION: *Rocky Mountain*
YEAR : *1982*

LOCATION/ PROJECT #	DATE	APPLICATOR	TRADE NAME	ACTIVE INGREDIENT	EPA REG. NO.	PEST	AMOUNT OF PRODUCT	AREA TREATED	AMOUNT 100% ACT. INGRE
1401 / 01	*9/10/82*	*Jane Smith*	*Tordon 2K*	*2.3% picloram*	*464 - 333*	*leafy spurge*	*50 lb.*	*0.5 acre*	*1.15 lb.*
1401 / 01	*9/13/82*	*Bill Jones*	*Tordon 2K*	*2.3% picloram*	*464 - 333*	*leafy spurge*	*20 lb.*	*0.2 acre*	*0.46 lb.*
1401 / 01	*9/16/82*	*Jane Smith*	*Tordon 2K*	*2.3% picloram*	*464 - 333*	*leafy spurge*	*30 lb.*	*0.3 acre*	*0.69 lb*

b. Accidental exposures:

1) who was exposed
2) how
3) what material
4) treatments (by whom and what methods)
5) results

c. Blood samples (for detecting cholinesterase inhibition)

1) from whom
2) by whom
3) when
4) where
5) results
6) where are records stored
7) if results positive, what actions were taken?

AN ECOSYSTEM PERSPECTIVE

To summarize, using IPM means taking a "whole systems" or ecosystem management approach to solving a pest problem. A particular ecosystem is usually thought of as containing:

1. ABIOTIC (non-living) components
   - a) sun
   - b) air
   - c) soil
   - d) water
2. BIOTIC (living) components
   - a) plants
   - b) herbivores (animals that feed on plants)
   - c) carnivores (animals that feed on animals--there may be several levels, see Figure 4)
   - d) detritivores (organisms that break down plant and animal material to smaller organic compounds)
   - e) decomposers--organisms that convert organic molecules to inorganic molecules.

   See Figure 4.

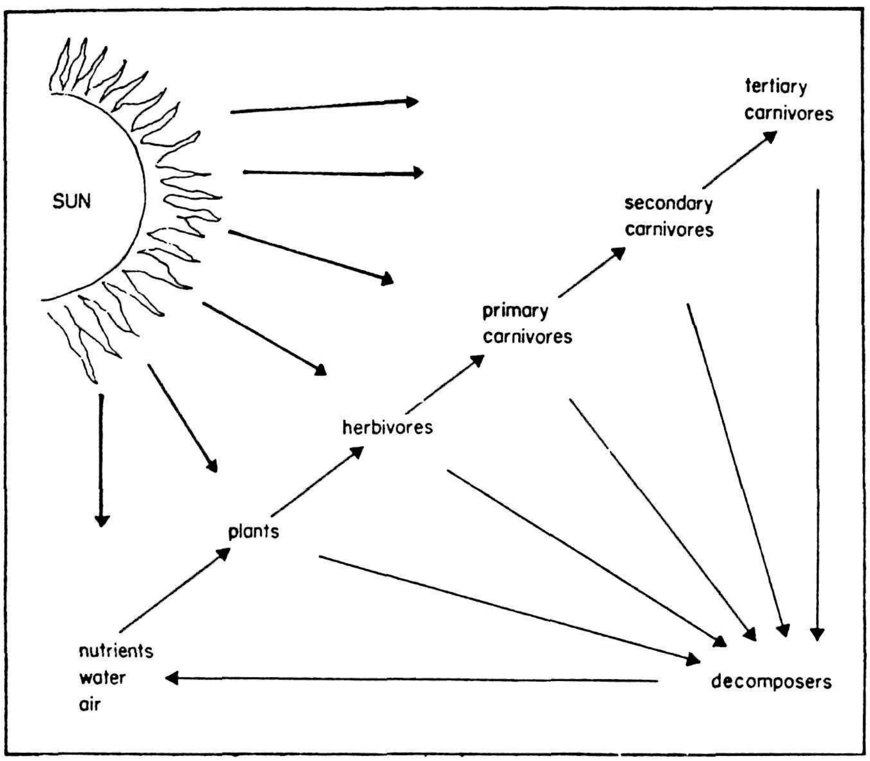
From the standpoint of the designer and manager of an IPM program, it is helpful to include another category:

3. SOCIAL/POLITICAL components
   - a) the members of a particular agency or institution
   - b) their constituencies
     - other agencies or institutions
     - professional associations and community groups
     - the general public
   - c) the political and legal constraints of the society at large

The many components of this ecosystem may be thought of as a series of nested boxes or systems each having impact on the other and all potentially impacted by a pest management program. See Figure 5.

FIGURE 4

A TRADITIONAL VIEW OF AN ECOSYSTEM

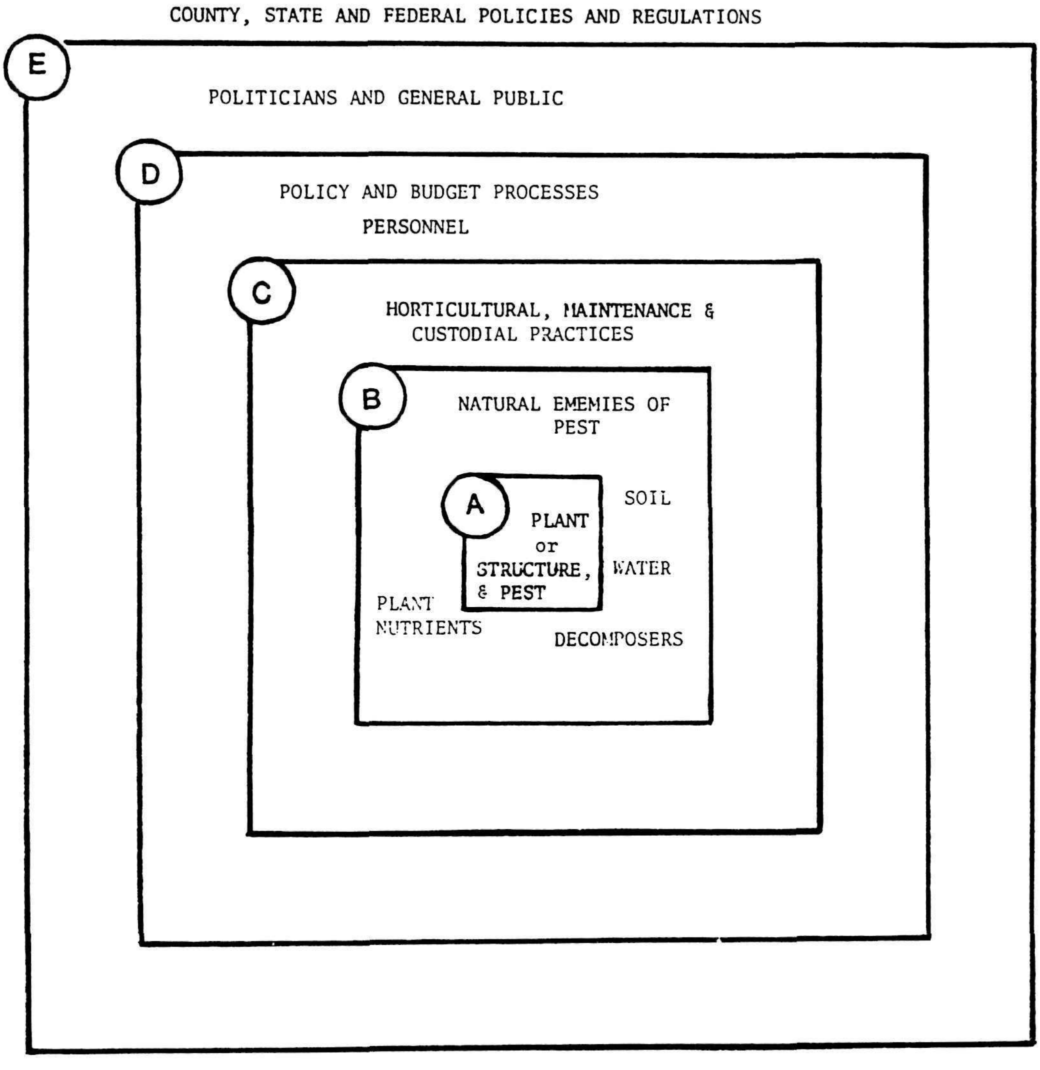


Arrows indicate energy flow. Reasoning behind approach to the problem: since all the ecosystem components are interrelated, by affecting one component you affect all others.

FIGURE 5

WHERE TO DRAW THE BOUNDARY?

A highly simplified view of the layers of physical, biological, social and political people and activities surrounding the pest problem.



To design and implement a successful IPM program at least to some degree it is necessary to be aware of and obtain information from each of these systems. This raises the classic problem in systems management: where to draw the boundary? If too much is included there is too much low-priority information to be processed. If the boundaries are drawn too narrowly (for example around only the plant and its pest, or a sink area and cockroaches) there is a risk that the solution to the pest problem will be excluded.

The remaining chapters of this manual describe a process for taking this "ecosystem" perspective and using it to design and develop a working IPM program for a public or private agency managing a park landscape and associated buildings.

Part Two

Making the Transition to IPM

INTRODUCTION

This part of the manual is designed to aid parks landscape and building personnel, supervisors and assistants, within public agencies or private institutions. The text is meant to be used by the person who will actually design the IPM program for a particular geographic area and then coordinate the implementation of the program.

DETERMINING THE NEED FOR AN IPM PROGRAM

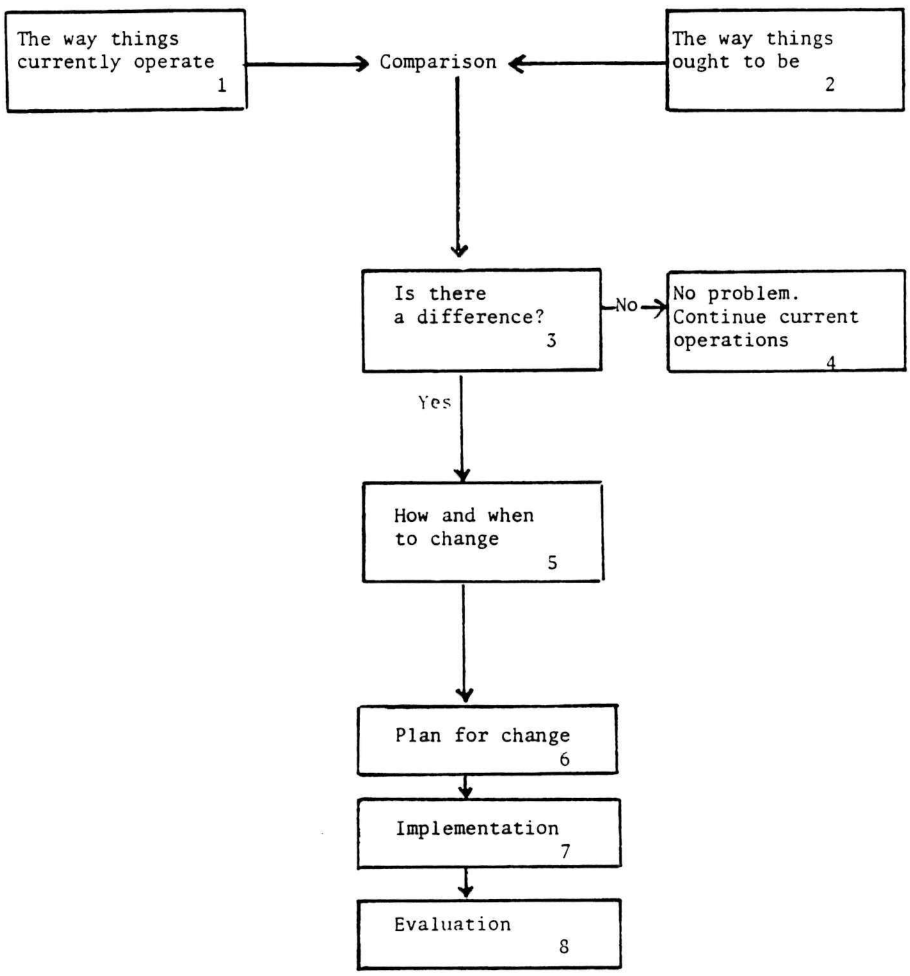
The decision to undertake the development of an IPM program may be based on:

- inadequate pest suppression
- high cost of current pest management
- need to reduce the use of toxic materials
- change in institutional policy regarding permissable pest management tactics, e.g. an institutional commitment to IPM principles

The reason behind the local decision to adapt a new system should have a determining influence on the design of the program, i.e. selection of pests to be targeted initially, people involved, and overall implementation strategy. A simplified view of the process for making a decision to change is described in Figure 6, "An Overview of the Change Process." The following discussion assumes that the comparison between boxes #1 and #2 in the Figure has been made and the conclusion of #3 is that the difference is great enough to warrant a change. The remainder of this manual deals with steps #5, #6, #7, and #8 shown in Figure 6.

FIGURE 6

AN OVERVIEW OF THE CHANGE PROCESS



PROGRAM PROGRESS--START-UP, GROWTH, MATURITY

The transition to an IPM program may last several months in a small system such as an apartment or food stand. In a large system such as a park or a building complex, several years of coordinated efforts may be required before the program is fully operational and institutionalized. This is because many people may have to be educated or trained both in-house and in the public, the right mix of strategies and tactics have to be proven in the field (which may take several seasons), and the appropriate combination of internal and external delivery of pest control services must be determined.

The transitional phase has three time periods:

Period	Activities
Start-up	1. In-house educational activities start on the objectives of the program and the process.
	2. Prioritization of pests for application of efforts.
	3. Collection of site and historical information.
	4. Design of monitoring process.
	5. Implementation of monitoring plan--field work begins.
	6. New techniques are tried where appropriate.
	7. Initial evaluation for effectiveness, cost and acceptance.
Growth	1. Larger-scale application.
	2. Training and education of in-house personnel and/or recruitment and guidance of outside vendors.
	3. Public support sought.
	4. Cost analysis continues.
	5. Modifications to initial program, e.g. monitoring system or treatment activities.
	6. Start research on difficult or unstudied pest problems and/or techniques.
Maturity	1. Monitoring routine.
	2. Fine tuning continues.
	3. Ongoing applied research continues.

PRELIMINARY ASSESSMENT - SOME BASIC CONSIDERATIONS

At the outset, the person responsible for designing the IPM program must answer at least the four categories of questions listed below.

1. Pest prioritization
   - What are the pest problems?
   - Which should be targeted initially for IPM implementation?

2. Information collection
   - Who knows about the pests and their control?
   - What information should be collected?

3. Past & current pest control program
   - How were the pest problems handled in prior years?
   - What is the pest control program at present?

4. Support for change
   - From whom can you expect support for development of an IPM program?
   - Where are the obstacles and resistance likely to materialize?

The answers to these questions will be found through the use of the following methods:

a) interviews, in person, by mail and telephone, of people within and outside of the agency

b) literature search

c) examination of records

d) initial site visits

PEST PRIORITIZATION

Each park or building manager has some kind of pest control program to deal with each of the top priority pests. Some of these pests may be under adequate control, at minimal cost and hazard. Others, by virtue of high cost, high environmental hazard, or excessive public complaints, are not being satisfactorily managed. These pests might be considered first for full-scale IPM implementation, i.e., monitoring, identification of injury levels, use of alternatives to toxic materials, and evaluation of treatments. In other cases, if you are inexperienced, choosing a less-visible or sensitive problem to begin with might be advisable. It is always easier to build a program on small successes. A pest is a good candidate for full-scale IPM implementation if it meets the following criteria:

1. The pest, or control program, is a threat to human safety or significant resources.
2. The current control program requires large expenditures.
3. The pest is not being effectively controlled with the current program.
4. A specific new tactic appears promising in terms of pest population suppression.
5. The envisioned program is politically and socially feasible and/or desirable (e.g. consistent with institutional policy and public attitudes, or involving pests regarding which there has been political pressure).

In many cases it will be easy to decide which pests and/or sites should be included in the initial IPM design. Often a particular pest problem is the original reason for deciding to develop the program. Sometimes there will be close agreement on which problem to be tackled among everyone interviewed who has an intimate view of what is happening in the field. It is important to take advantage of such situations since they are more likely to produce cooperation with the new program.

In cases where there is dispute about pest severity or it is unclear technically which problems should be tackled initially, it is wise to reserve judgment until all five criteria have been given an initial survey. Deciding factors may turn out to be:

- sources of management information that are extensive, close at hand and/or available regularly
- control tactics that are easy to implement because they are simple or very similar to tactics presently applied
- political support that is particularly favorable

INFORMATION COLLECTION

When you have developed a general or prioritized list of pests, you need to know where to get useful information and what information to look for. It is essential that the information you collect be assembled in a systematic way. Bear in mind that you may need to locate information quickly, that others may need to have access to the materials, and that coordination of the program and maintenance of the file may eventually be passed on to someone else.

Pest Management File

Develop an alphabetized file of available technical specialists, including:

1. Name of organization/person
2. Phone number/address
3. Consultant rate (if any)
4. Brief summary of area of specialization

A request-for-assistance (form letter) can be sent to interested individuals or organizations (university researchers, Extension Service, Park Service specialists, etc.) that could be drawn on when needed.

Important reference books, publications, and reference collections (pest and host specimens, photographs) can be incorporated into the alphabetized file.

The file can be cross-indexed by pest, plant, or type of area (desert, wilderness, historical buildings), etc.

Collecting Initial Information on the Pest

It may be easier to collect and store information about the pest organism if it is organized and summarized. Then all the most pertinent information is synopsized at a glance and there are references to the in-depth materials on each item. On Sample Form 2, "Insect Pest Information," it is assumed that some of the information would not be assembled initially, but would be acquired as a monitoring program is established. The actual questions would vary according to whether an insect, weed, microbe, rodent, etc. was being surveyed. The information that should be collected initially includes:

1. The biology of the pest: its life cycle, geographical origin, natural enemies, other major limiting factors, phenology and population dynamics.
2. The biology of known natural enemies: their life cycles, stage of host attacked, percentage of host population killed, specificity, their natural enemies, etc., phenology and population dynamics.
3. The biology of the host or the ecosystem surrounding the pest: life cycle, stages or areas attacked, other herbivores on pests, major limiting factors, phenology and population dynamics.
4. Monitoring techniques: methods to sample host, pest and natural enemies species, damage caused by the pest, weather and other important variables, including maintenance activities and other actions and perceptions of humans directly and indirectly involved.
5. Injury levels: a method to anticipate when pest populations will produce intolerable structural, medical, economic, or aesthetic damage.
6. Non-toxic management techniques: these include design elements, habitat modification, horticultural, physical, and biological methods, as well as chemical tools like attractants and repellants.
7. Chemical suppressive techniques: these are botanical or synthetic chemical tools used to quickly suppress an outbreak of a particular pest. Ideally, these should be selective or selectively used.

Sample Form 2

INSECT PEST INFORMATION

PEST NAME: ____________________

Scientific name: ____________________

Hosts of particular interest: ____________________

____

Country where pest is native: ____________________

Natural controls: (include parasites, predators, pathogens, competitors, as well as specific environmental controls) ____________________

____

____

Life Cycle

Overwintering stage: __________ Where: __________

Where eggs are laid: ____________________

Larval food: ____________________

Adult food: ____________________

Total generations per year: ____________________

Date when feeding begins for each generation: __________

Does any of this information collected in the field differ from the literature? If so, how? ____________________

____

Special behaviors: ____________________

____

Type of damage: ____________________

Monitoring methods: ____________________

____

Injury level (economic and aesthetic): ____________________

____

____

____

(continued on reverse)

Management tools (include abreviated reference to source):

Toleration: ______________________________

Public education: ______________________________
(to reduce litter, change behavior, etc.)

Habitat management/design-redesign: ______________________________

____

Horticultural (plant resistance, mowing, fertilizing/composting/mulching, etc.): ______________________________

____

Physical (hand removal, pruning, barriers, traps, etc.): ______

____

Biological (raptors, predaceous insects, parasitoids, etc.):

____

Chemical (attractants, repellants, hormones, sterilants, poisons):

____

Treatment threshold: ______________________________

Spot treatments possible: ______________________________

Safety: ______________________________

____

Effectiveness: ______________________________

Identification keys/photographs or reference collections (references):

Pest: ______________________________

____

Host: ______________________________

____

Natural enemies: ______________________________

____

Important general references: ______________________________

____

____

Collecting Initial Information on the Site

Soil types, plant species, and adjacent land uses may vary widely among sites. The collection of background information on the site(s) being managed provides a baseline for beginning a monitoring program. It also provides an overall context for evaluating the data collected during the monitoring process and for making management decisions based on that data.

Site background data also permits the pest manager to establish priority areas for allocation of further monitoring and maintenance resources. Sites shown to have chronic pest or structural problems can be assigned higher priority for monitoring or maintenance work than areas with little or no history of such problems.

Temperature and other climatic conditions should be assessed for each site in question. By noting their effect on pest populations and their controls, treatments can be developed and timed for greatest effectiveness. Questions to ask about a site will vary according to whether a landscape, a structure or both are being assessed. Sample questions are: (see Sample Form 3).

- When is this information being collected?
- Where is the site(s)
- Who is providing the information?
- What is the basic problem that led to the site assessment?
- How long/wide/extensive is the problem?
- What is the condition of the: soil, plant(s), surrounding structures?
- What other pest problems exist at the site besides the target pest?
- How characteristic of other areas is this particular site?
- What are known relevant social factors?
- How old is the structure or the landscape in question?
- What is probable cause of the problem?
- What do earlier records (if available) show?
- How much money is allocated to manage this problem?
- Who has been responsible for this site in the past?

INITIAL SITE VISIT

Date: ______________________ Observer: ________________

Park area: ____

Pest identification: ____________________________________

Pest abundance: ____

Damage: ____

____

Probable sources available to pest:

Food: ____

____

Water: ____

____

Shelter/harborage: __________________________________

____

Condition of plants or structure: _______________________

____

Other pest problems at site: ____________________________

Is this site characteristic of other areas: _____________

Relevant social factors: ________________________________

____

How old is the structure or landscape?: _________________

Probable cause of the problem: __________________________

____

What do earlier records show?: __________________________

____

Amount of money available to manage the problem: _________

Person previously responsible for the site: _____________

CURRENT PEST MANAGEMENT PROGRAMS

History of Current Programs

Very often, by the time a decision has been made to develop an IPM program, the original impetus for change has already caused a modification in the way the problem is being handled. However, prior management of the problem might have had an impact that may still be having an effect; for example, through reducing natural enemies or competitors of the pest, favoring the rise of environmental conditions favorable to the pest (a positive feedback situation), leaving toxic residues that decompose very slowly, etc. Therefore, through interviews and examination of records, it is important to learn:

- What pest control tactics were applied in prior seasons?
- What materials were used? Where? When? How much?
- What equipment was used?
- Which personnel were involved?
- What records were kept?
- How effective were the treatment activities?

Status of Current Programs

Essentially the same information suggested above must be collected about recent and ongoing activities, but in somewhat greater depth. Information should be collected not only on what is being done, but also on how well these activities are understood by those performing them. A questionnaire, such as those shown in Sample Forms 4, 5 and 6, can be used to gather information on the whole pest management system at present, i.e., the availability of trained personnel, appropriate equipment, etc. This information will later become useful in recruitment, job description changes, planning shifts in maintenance operations, purchasing equipment, etc. The overall system for initiation of a pest control operation (due to a visitor complaint, as a result of crew observations, etc.) can be included in this analysis.

Sample Form 4

PERSONNEL SURVEY

To:__________________________ From: Park Superintendant Date:__________

Re: Resources in Pest Management (or Related Fields)

Please fill out this form and return to my office in one week. For additional space use the reverse side.

1. Employee Name (Last, First):______________________________
2. Park:____
3. Phone Number (Work):________________
4. Present GS/WG Level:________
5. No. Years Employed in Park Service:_________________________
6. No. Years Employed as Pest Manager in Park Service (if appropriate):_____
7. Present Job Title:______________________________________
8. Immediate Supervisor:___________________________________
9. Previous Job Title:_____________________________________
10. Highest Educational Level (last grade completed):______________
11. Special Awards/Degrees in Pest Management or Related Fields (e.g., Horticulture):
12. Attendance at Pest Management Related Courses/Seminars during Past 3 Years:
13. Pesticide Certification (s):
14. Previous Employment/Experience in Pest Management:
15. Present Duties:
16. Major Sources of Information Re: Pest Control Decisions (publications, people, organizations):
17. Do you make decisions regarding pest management? If so, what type?
18. Suggested Changes in Pest Management Practices:

Sample Form 5

EQUIPMENT SURVEY

1. Park: ____

2. Person Completing This Form: ____________________ Title: __________

3. Pesticide Application Equipment:

Type	Approximate Cost	Estimated No. of Hours Required for Maintenance/Year

4. Major Pieces of Equipment Related to Care of Ornamentals (aerators, shredders, water trucks, etc.)

Type	Approximate Cost	Estimated No. of Hours Required for Maintenance/Year

5. Equipment Needs:

Sample Form 6

ANNUAL MATERIALS USE SUMMARY SHEET

Strategy (e.g., fly traps, pesticide)	Target Pest	Amount Used	Cost	Effectiveness Good-Fair-Poor

Important questions to be asked of people who are currently managing the pest problem or have done so in the past are:

1. Have the PERTINENT BIOLOGIES of host and pest (including information on pest food, water, habitat needs, and behaviors) been determined? This information is essential because it provides valuable clues as to when and how to intervene in the pest's normal life cycle to control it.
2. Is the pest being MONITORED? How? At what cost? What are the findings?
3. Have INJURY AND ACTION LEVELS been established? (These may exist in an informal fashion being articulated or quantified.)
4. What PEST SUPPRESSION TECHNIQUES are being used? At what cost and benefit?
5. Is there a RECORD KEEPING SYSTEM?
6. Are procedures being used to EVALUATE whether the current pest control system is working?
7. Which PERSONNEL/EQUIPMENT/RESOURCES are being utilized?

SUPPORT FOR CHANGE

A successful IPM program will require the enthusiasm and cooperation of many people. At the same time it will undoubtedly mean a change in how things are done. In addition, it will probably require at least the reallocation of present resources, if not the acquisition of new ones. What is done first, and how, may in part be effected by who is supportive of the program initially. As a designer and coordinator of the program you need to know:

- How extensive is the general support for change in the pest management system? Within the immediate institutional hierarchy? In the surrounding community?
- From whom can you expect direct support for the implementation of the program?
- Are the supporters of the change aware of the time required to design, implement, evaluate, and fine tune the program and to transfer the technology required?

Challenges

Assuming that the local park hierarchy remains supportive over the period of program development, there are still a number of potential obstacles that can arise to slow the evolution of the project or frustrate its implementation:

1. Unanticipated costs or cuts in personnel or other resources.
2. Changes in personnel.
3. An unrealistic timetable that falsely raises expectations and causes loss of support when unfulfilled.
4. Psychological barriers to change.

While often little can be done about the first, precisely because they are unexpected, the latter three obstacles must be anticipated in the planning process. Of all four, the last is the most common and may be the most serious.

Psychological barriers

The adoption of the IPM program is likely to depend on the ability of the designer/coordinator to understand and overcome psychological resistance to the changes that may be proposed. It is important to become aware of what positive reinforcements people may be receiving that encourage them to continue to use the familiar behaviors and the negative reinforcements that discourage them from adopting a new model. Examples of psychological resistance are:

- Inertia--adapting an IPM approach usually means instituting some change. Any change requires increased attention and mental effort.
- Negative implication regarding past performance--people generally want to assume that they have been doing their jobs well. Requests to change may suggest poor past performance and erroneous past decisions.
- Loss of personal, supervisory or territorial authority--if an impersonal decision-making procedure is instituted, based on quantified data from field monitoring, people may feel their

personal power to make decisions is being eroded.

- Imagined difficulty in learning new technology--the techniques used in IPM may appear to require conceptual and operational skills beyond the person's ability.
- Fear of program failure--many people find it very difficult to participate in something new to them. They may only be comfortable doing so if they understand it is not really new or that it has been done successfully somewhere else.

Anticipate Resistance

Overcoming obstacles to the implementation of any program requires attention to both design and style. The following suggestions are offered to maximize the chances of the program's success.

- Include at least one short-term objective in the plan. When dealing with a number of pest problems, identify one of the pests likely to respond quickly to an IPM approach so a short-term objective can be realized.
- Share the process. Involve all key personnel in the day-to-day IPM program development as early as possible and to the degree appropriate to their positions in the agency. Acknowledge the contributions of others whenever a milestone is achieved or an activity has a successful outcome.
- Build in redundancy. Prepare written and visual products that will remain in the agency for reference when you and others now associated with the IPM program are no longer directly available.
- Emphasize communication. Tailor your information to the formal and informal communication formats of the agency. Tell people:
    - what will happen (the plan)
    - what is happening (the action)
    - what happened (the result)

In general, if anything goes wrong, check your communication system first.

DEVELOPING THE MONITORING SYSTEM

As outlined in Part I, the purpose of a monitoring system is to:

- Collect baseline field data on existing pest control practices
- Compile data on which to base pest control decisions
- Evaluate effectiveness of treatments including modifications to the design or maintenance of the system and the education and training program

Generally speaking, a fully operational monitoring program should observe, on a regular basis, the pest population, the natural enemies of the pest, potential pest populations, maintenance activities, random human and other events, and weather. A list of the observations that should be recorded is presented in Table 1.

SAMPLING

Sampling techniques are used to measure the population size of a pest or any organism active in the system. Select sampling techniques that can be utilized with available resources and within the time allotted. The samples should provide information from a part of the system that is sufficiently representative of the whole. The following process is suggested.

1. Determine the purpose for the sampling. For example, you might establish a sampling program to time pesticide treatments, to release natural enemies, to relate pest population size to weather, or to discover more about the biology of the pest or its natural enemies.
2. Determine which populations are to be sampled. For example, in managing most pests, there are many predators and parasites that could be monitored. Some populations may be more important or easier to sample than others. A decision must be made and monitoring forms developed.

TABLE 1

FACTORS INVOLVED IN A MONITORING SYSTEM

		RECORDED OBSERVATIONS
THE PEST COMPLEX		
	Baseline data:	Who knows about the pest and related organisms; what to look for; where to look for it.
	Pest Identification:	Biology/life cycle; sampling information (population size, density, distribution, injury/action level).
	Host/Natural Enemy & Related Organisms Identification:	Biology/life cycle; sampling information (population sizes, density, distribution).
THE MANAGEMENT/SITE COMPLEX		
	Baseline data:	Current management program's history and status; costs of activities, including horticultural; site description/ variables (including weather); previous activities and their costs, including horticultural activities, other treatments, and equipment used; waste management; short and long-term effects of activities on target pest and on ecosystem. IPM activities and their costs, including strategies used and effects.
RELATED FACTORS		
	Baseline data:	Support for change, obstacles.
	Unanticipated Events:	Actions or perceptions of humans; random events, i.e. accidents, vandalism, weather abnormalities.

3. Decide on the <u>frequency of visits and which sites</u> should be inspected. High priority areas can be visited weekly or more frequently during sensitive periods. Less visible or affected sites can be checked just often enough to compare with the others.
4. Determine the <u>number of samples</u> to be taken at each site. It usually takes two or three seasons to determine the minimal number that can be checked and still provide enough information on which to base decisions.
5. Decide on a precise <u>sampling procedure</u>. With outdoor pests it will also probably take two or three seasons to determine the least amount of sampling needed and the best way to obtain reliable data. More than one technique or sample size may have to be tried to determine this.
6. <u>Describe the sampling procedure in writing</u>. Write down the activities in the sampling process so that different personnel can do the sampling without introducing changes. A written procedure also helps analyze and document the process used to obtain various samples at different times.
7. Make an easy-to-use <u>recording system</u>. The person doing the sampling in the field should have a minimal amount of writing to do. As much as possible should be recorded by checking off or circling the appropriate number or comment. It may take several revisions to arrive at the most useful record sheet.
8. Develop a system for <u>display of field data</u>. The information collected in the field must be assembled in a meaningful way so that visible patterns emerge quickly, to facilitate decision making.
9. Determine <u>who</u> is the best person to carry out the sampling in the field. This person will need to be trained and then supervised to make sure the data is being collected in the manner originally intended and demonstrated.
10. <u>Evaluate</u> the sampling and decision-making system. As you begin to assemble data, possible changes in the sampling process may be noticed that could improve precision, accuracy or significance. Make

notes of such ideas for later use. If the system did not adequately warn of damaging population trends, then it should be redesigned.

11. Make corrections in the sampling and decision-making system. Record the changes so a written history is maintained for later review purposes.

The following form (#7) indicates how field data was collected with the azalea lace bug problem in LBJ Grove, NCR in 1981. Note that the form indicates a plot number which is shown on the map following the form. With a map the original plots can be found for comparison and additional study at a later date.

AZALEA LACE BUG SAMPLING

Date 5/7/81

Park LBJ GROVE   Bed AZALEA PLOT #3

Recorder GIRALDI   Photos: yes no   Maps: (yes) no   #of Map 1+2

Bush#	Leaf#	#Bugs	Leaf Damage (0-4)*	Bush#	Leaf#	#Bugs	Leaf Damage (0-4)*
1	1	1	0	6	1	0	2
	2	0	0		2	7	4
	3	0	0		3	1	1
	4	0	0		4	1	4
	5	3	3		5	0	0
2	1	0	1	7	1	8	3
	2	1	1		2	0	0
	3	0	0		3	1	1
	4	0	0		4	7	2
	5	0	1		5	1	0
3	1	14	4	8	1	2	2
	2	2	3		2	0	0
	3	2	2		3	0	0
	4	1	1		4	0	0
	5	6	1		5	2	1
4	1	0	0	9	1	0	0
	2	0	0		2	1	3
	3	0	0		3	0	0
	4	1	1		4	0	0
	5	0	1		5	3	4
5	1	0	0	10	1	0	1
	2	0	0		2	0	0
	3	0	0		3	0	0
	4	0	0		4	0	0
	5	0	0		5	0	0

Totals

#Bugs= 65   Sum of all Damage 47

Ave. #Bugs= 1.3   Ave. Amount of Damage 0.94 ~25%

Stage of Bugs: (nymph or adult) nymph

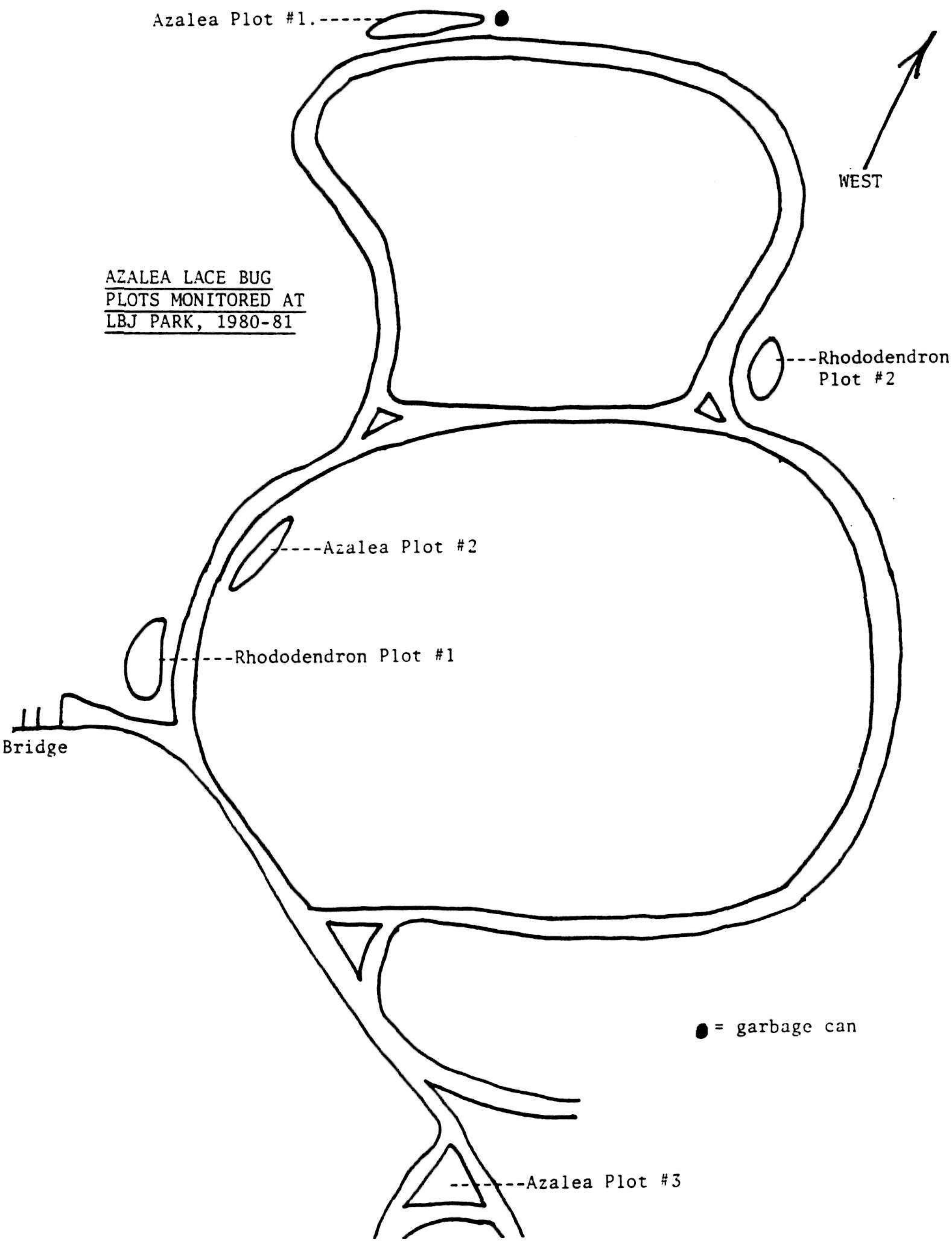
Presence of Predators:

Recommendations: Treatment w/ soap recommended because of continued presence of lace bugs and total damage suffered by several leaves,

Comments: eventhough lace bugs were already reduced by 5/6/81 1.25% soap treatment.

* 0=0%; 1=25%; 2=50%; 3=75%; 4=100% stippling

(This map accompanies Sample Form 7.)



DETERMINING INJURY LEVELS

- A key concept in IPM is the use of an "injury" or "tolerance" level to determine if the problem is serious enough to justify some kind of treatment. The subject of injury levels was introduced, in simplified form, in Part I.

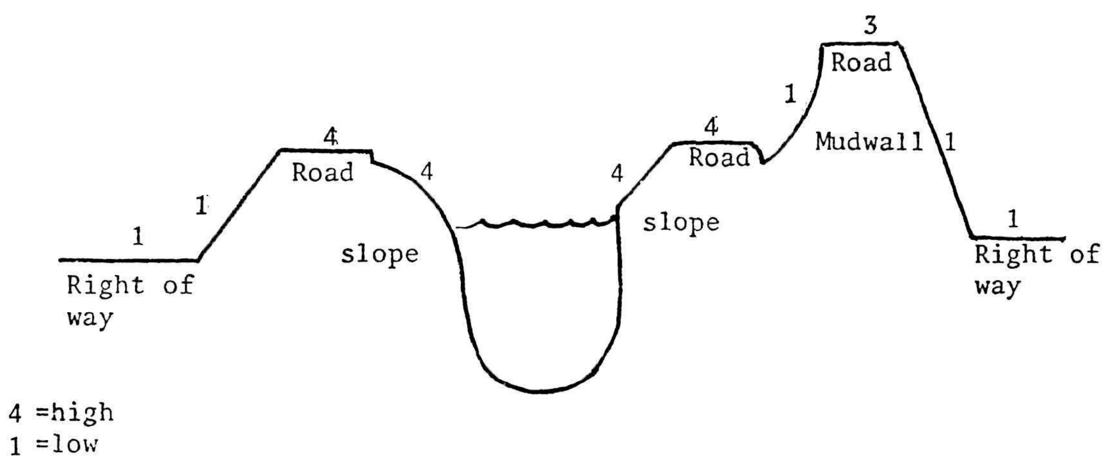
- The process of determining an injury level and then making the comparison with field samples before taking action is crucial to the whole IPM program. Pest management activities that are not absolutely necessary waste money and resources, may prolong or exacerbate the problem, and may disrupt food chains. This latter problem has special significance to natural areas of national parks where as many food chains as possible should be preserved--even those including some pestiferous or potentially pestiferous species (such as the mosquito). It may be less important for inner city, intensively managed landscapes. Finally, unnecessary activities may impair the historical authenticity of a landscape or building.
- Since tolerances of damage or pest visibility differ so vastly, injury levels for urban or non-crop systems actually amount to an agreement or compromise among the people involved on what the tolerable levels should be.

- The discussion in Part I identified pest population size, pest species, and the location of the pest problem as key variables in determining an injury level for any pest in any site.

Ranking the Variables

As part of the process of deciding on an injury level, the geographic locations within the area to be managed can be ranked according to how critical they are in terms of direct damage by the pest or human sensitivity to cosmetic changes produced by the presence of the pest. For example, a visitor center might be ranked as critical, a picnic area as less so (toleration of more damage or change) an infrequently visited trail least sensitive. Another example: in an IPM program for managing weeds along the California State Aqueduct System, the various areas were ranked according to their location as indicated on the cross section below.

LOCATION RATING FOR
VEGETATION DAMAGE TO AQUEDUCT



The process of ranking the various locations is valuable because it provides a basis for discussion and decision making. The involvement of key people in the process is needed to arrive at an agreement as to which are the areas that should be most intensively managed and where there is justification for the interference through pest suppression in the naturally occurring plant and animal systems. In addition to location, there are other variables that will effect injury levels.

Other Variables Affecting Injury Levels: Micro-habitats, Cultivars, and Plant Physiology

Quantification of the injury level (e.g. so many bugs or weeds, per so many leaves or square feet of turf, etc. equals unacceptable damage as is common in agricultural settings) is made difficult by the fact that compared with an agricultural field an ornamental landscape may offer much more variation in micro-environment (soil, light, water, air pollution, compaction, etc.) and horticultural cultivars. The same number of pests will not necessarily cause the same amount of damage if the plant is in full sun or shade, in sandy or clay soil, next to the road or on a set-back, etc. And, mixed into a single planting of what appears to be the same species, cultivars with entirely different degrees of susceptibility to damage or competition from the pest organism may appear.

A further complication is that due to changes in physiology, the same plant may be differently susceptible to damage from the same number of pests (insects), innoculum (disease pathogens) or competitors (weeds) at different points in the season or life cycle of the plant. Even within a building, micro-environmental variations can have profound effects on pest population sizes and injury levels (e.g. compare the problem of having cockroaches in the bathrooms versus in the boiler room).

In summary, injury level will need to be determined for each pest in each site . For example, the following factors must be taken into account when the level is quantified for a pest on a plant.

- pest species
- pest numbers
- plant cultivar
- physiology of the plant (time in season)
- environment of the plant
- location of the problem in terms of visibility, economic or medical implications
- local concensus on what is tolerable

Because of the number of variables that must be considered, the process of determining a specific injury level in the field can best be described as asking a series of questions, i.e. is the plant cultivar X or Y? Is it in the sun or shade? etc. Some suggestions on transferring this kind of process to field personnel are offered in Section VI.

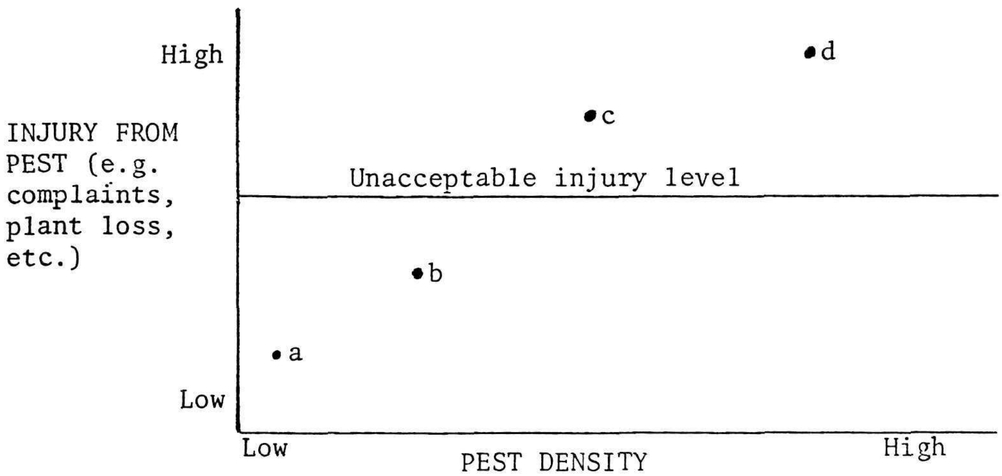
A practical approach to determining an injury level is to take the successive quantitative observations of the pest population, as obtained from the monitoring/sampling program, at specific locations, and relate them to visible plant damage and/or adverse reaction on the part of visitors or staff. For example: at a certain site, X pest is present with a certain average density (e.g. 10 aphids per leaf, 10 caterpillars per 25 inches of branch, 18 larvae per dip, 5 cockroaches per trap, two rat holes per 100 sq. feet, etc). This density is correlated with certain events. (Example: X number of complaints or bites, 25% browning of the leaves or defoliation of the plant, or a heavy layer of insect frass on the picnic tables, noticeable pigeon droppings on the walkway, etc.). See Figure 7.

The process of recording and summarizing the information in this fashion will encourage two events: making explicit whatever working injury level has been in use before (example: last year a chemical control was used when the aphid infestation in the cherry trees was first noticed by a staff person) and evaluating its appropriateness (example: 100-500 aphids per foot of tulip tree branch is not producing any visible change in the plant or any complaint; or, one rat hole within 100 square feet of the concession is intolerable).

Because of the many variables involved (such as weather), with many animal pests usually two to four seasons are required to determine an injury level with any certainty. But in management programs it is necessary to start with a "working injury level" the first season and then revise that up or down as experience is gained. The determining factor in park landscapes may turn out to be the political one--who complains strongly or most frequently--just as the market price for the commodity may be critical in production/crop systems. These determining factors may vary from year to year with consequent effects on injury or "tolerance" levels.

FIGURE 7

HYPOTHETICAL EXAMPLE OF UNACCEPTABLE INJURY LEVEL



a - d represent successive samples of injury and pest population density. a and b are tolerable levels, while c and d are intolerable injury levels.

In some situations, at the beginning of the first season, guidance on setting the injury level may be available from the literature on the pest, through oral discussions with those experienced in managing the pest elsewhere, or from your own or other local recollections of the problem in prior years. However, the initial level set should always be regarded as tentative because of the site-specific nature of the determination. Remember, the objective in setting an injury level is to obtain guidance for deciding when to take action so as to adequately suppress the pest where necessary while at the same time minimizing ecosystem disruption and wasted resources. Thus, one of the functions of explicitly setting an injury level is to heighten awareness that there may exist levels of the pest population where no need to take action exists.

DETERMINING DECISION AND ACTION POINTS

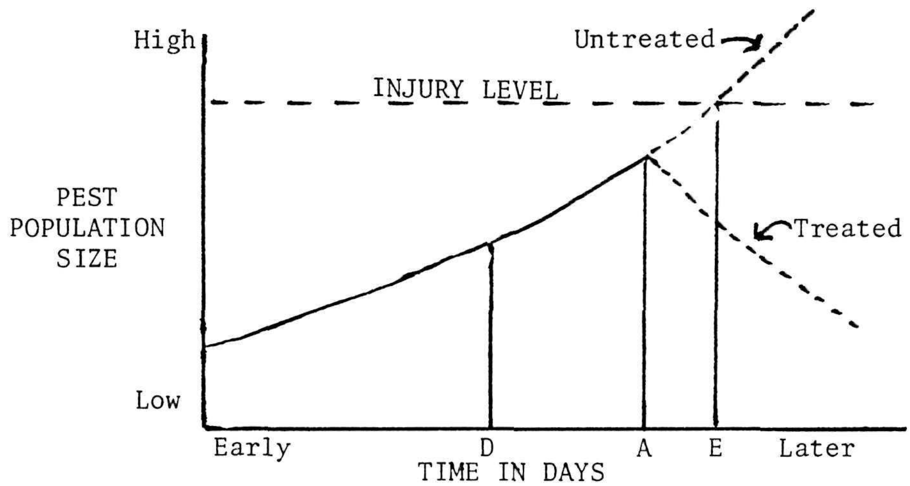
The action point is that point in time when treatment action(s) need to be initiated in order to prevent the pest population from reaching the injury level. The decision point is that point in time when plans for the treatment action must be started. As Figure 8 indicates, the action point should come before the injury level is reached. The decision point will come some time before the action point.

Each treatment requires preparation time. One can call this preparation time the action preparation time. Working backwards in time from the action point, one can determine a point in time when a decision about each treatment must be made and plans for action should start if intolerable damage is to be prevented.

If one expects the pest population to exceed the injury level at X, and the action preparation time to be, for example, 3 days, then the decision point is D, or A minus 3 days. If one wants to delay decisions and action points as long as possible, which is desirable, then plan ahead and make as many advance preparations as possible to keep the lag time short. The shorter the action preparation time, the more time for decision making. This increases the reliability of decision making and chance of avoiding treatment altogether.

FIGURE 8

INJURY LEVEL, ACTION POINT (A), DECISION POINT (D)



D = Decision point
A = Action point
E = Expected time when unacceptable injury level will occur
______ = Observed pest population
------ = Anticipated pest population

However, determining the action point involves more than simply working back from the injury level. This is because pest population dynamics are difficult to predict with precision. In fact, population dynamics is among the most complicated problems in biology. There is no simple way to provide an error-free method for every pest situation.

The following discussion is offered as a practical approach to determining action points when many variables must be taken into account.

The two major kinds of information that must be taken into account are biological/site factors (those that are intrinsic characteristics of the pest and its environment), and social/mechanical factors (those that are features of the administration and bureaucracy responsible for pest management).

Biological/Site Factors

Information on the pest and its population size will be gathered from monitoring, as discussed in the previous section. Several questions about the population must then be asked:

- How does the pest population size compare with the working injury level?
- If the population size at present is below the injury level, how likely is it to grow to damaging levels (to the injury level)?
- How fast is the pest population likely to grow?

The ability to judge the pest's tendency to grow depends on the pest manager's experience in considering these factors, and his or her personal knowledge or awareness of the literature on the biology of the pest. Basic considerations are:

Life cycle factors (number of generations expected per season; ratio of eggs or young to adults, etc.)

Natural enemy activity (how many natural enemies are present, how effective they are in reducing the pest population, etc.)

Growth rates of the pest and its natural enemies (food sources for the pest and its enemies, etc.)

Emigration or immigration of the pest or its natural enemies (likelihood of the species or natural enemies emigrating or immigrating--Emigration: to leave a site never to return; Immigration: to move into a site or location and remain; Migration: to move periodically, usually to and fro, with the seasons, crop or favorable locations).

Weather (how the near-term weather affects the pest and its natural enemies)

If a graph of a pest population's growth over time is available from previous seasons, from published work on that species, or can be constructed from observation, then rates of population growth can be developed for the future. Similar graphs should be developed for the natural enemy populations.

If data about the target pest is nct available, then data from a more thoroughly studied, closely related species may be used to provide guidelines for predicting the growth rates of the target species.

Site considerations such as human accessibility and vulnerability to damage may change with the seasons. Certain life stages of the pest may be more susceptible to the preferred treatment activities than others. For example, in most cases mosquitos should be suppressed in the larval stage; "smoke bombs" (a fumigant cartridge) should be used against ground squirrels in the spring when adults are mating; and certain translocating herbicides are more efficient if applied in the fall when the plant is moving sugars to its roots. Windy weather, spring thaw, or other weather conditions may make some sites off limits for equipment or spray applications or in other ways make human activity difficult. The pest manager must take as many of these possibilities into consideration as possible. In addition, some time for the unknown or uncontrollable variables should be allowed.

Social/Mechanical Factors

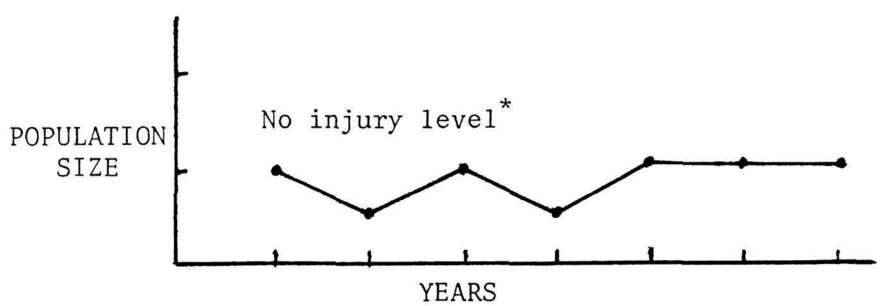
The social/mechanical factors determine the amount of action preparation time that should be anticipated. Considerations include time to get approval for actions, time to get supplies, move equipment, or locate labor, acquire purchase orders, handle paperwork involved with certain restricted materials, etc. The more information on the biological/site factors that has been collected and analyzed, the more rationally social/mechanical factors can be managed, because decisions about supplies, equipment, and other resource allocations will be made against hard information about the pest rather than changeable inclinations of various personalities in the management hierarchy.

Decision-making in the Face of Uncertainty

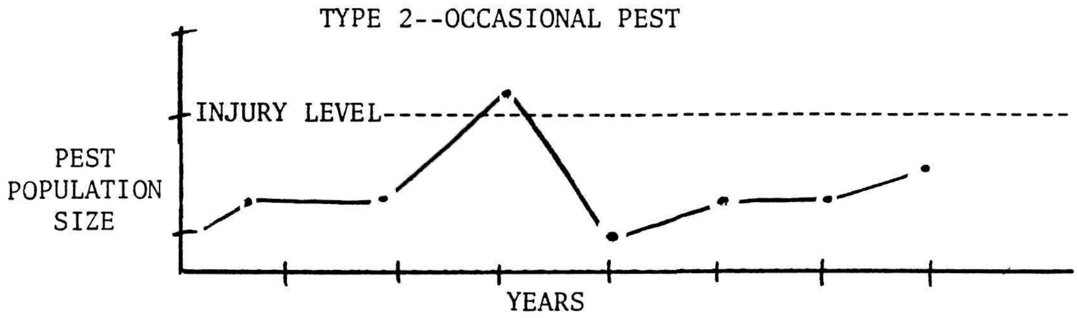
The preceding general statements about pest population dynamics apply to all kinds of pests--insects, vertebrates, and microbes. Insect pest problems, however, create particularly difficult predictive problems because of the speed with which their populations can expand and because of the numerous factors, especially little-known natural enemies, that affect their survival. The following discussion presents five types of pest situations. In reality, pests often have many generations per season and several peaks per generation, but in this discussion we are representing only one peak per season.

Type 1 (No Problem) is a situation in which the "pest" population fluctuates from year to year but does not reach an injury level. Thus no treatments are needed, and to most people, this insect is not a pest. However, it may have been or is regularly treated (example: box elder bugs).

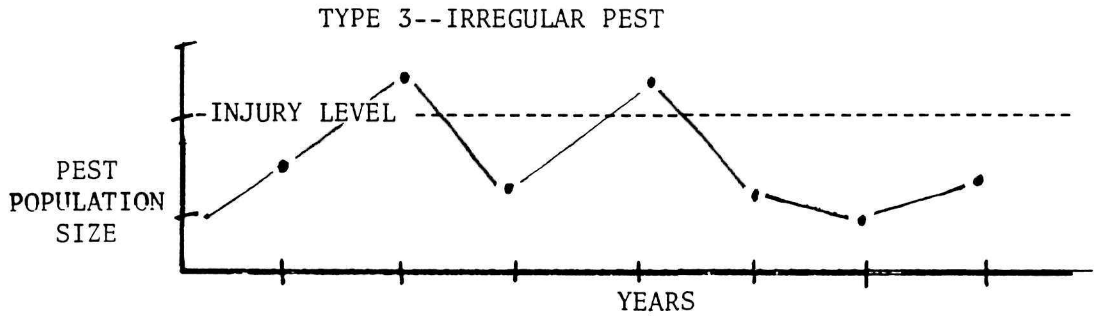
TYPE 1: NO PROBLEM



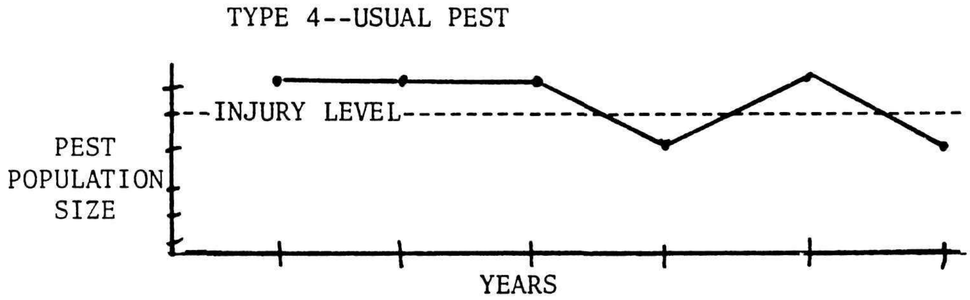
Type 2 (Occasional Pest) is a situation in which the pest population rises above the injury level in an occasional season. (Example: Southern pine beetle.)



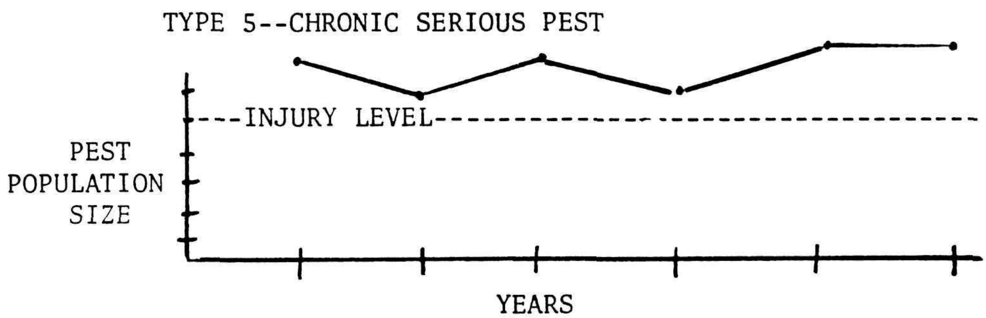
Type 3 (Irregular Pest) is a situation when the annual peak population frequently crosses the injury level. (Example: many aphid species, especially in garden or small farm systems.)



Type 4 (Usual Pest) is a situation where the pest population usually peaks above the injury level but sometimes drops below the injury level. (Example: elm leaf beetle, rose aphids.)



Type 5 (Chronic Serious Pest) is a situation in which the pest population hovers around the injury level, is usually above it (and rarely below it). (Example: cockroaches in kitchens.)



As monitoring data accumulates from year to year, the manager's predictive and planning ability increases. When Type 3 pests in the system being managed are clearly identified, resource allocations for monitoring can be made more readily. If the special needs of Type 3 pests are not understood, or the Type 3 pests are not identified, those making budget decisions may be unwilling to allocate funds for monitoring (it is not a "treatment," no "work" is being done).

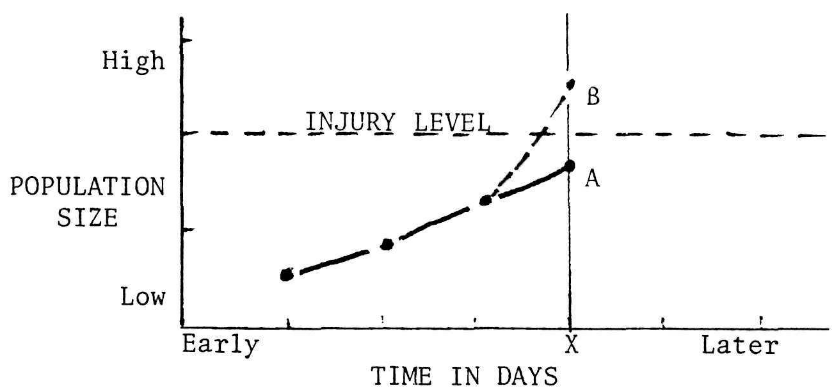
Factors Causing a Sudden Rise in the Pest Population

The four major factors that influence the rate of population growth and may lead to a sudden rise (shown in Figure 9) are:

1. Increased reproductive rates
2. Reduced pest mortality from natural enemies or other causes
3. Increased pest immigration rates
4. Increased natural enemy emigration rates

FIGURE 9

SUDDEN RISE IN PEST POPULATION CAUSED BY VARIOUS FACTORS



A = Expected population at time X
B = Sudden surge in population at time X
____ = Observed population
---- = Extrapolated population

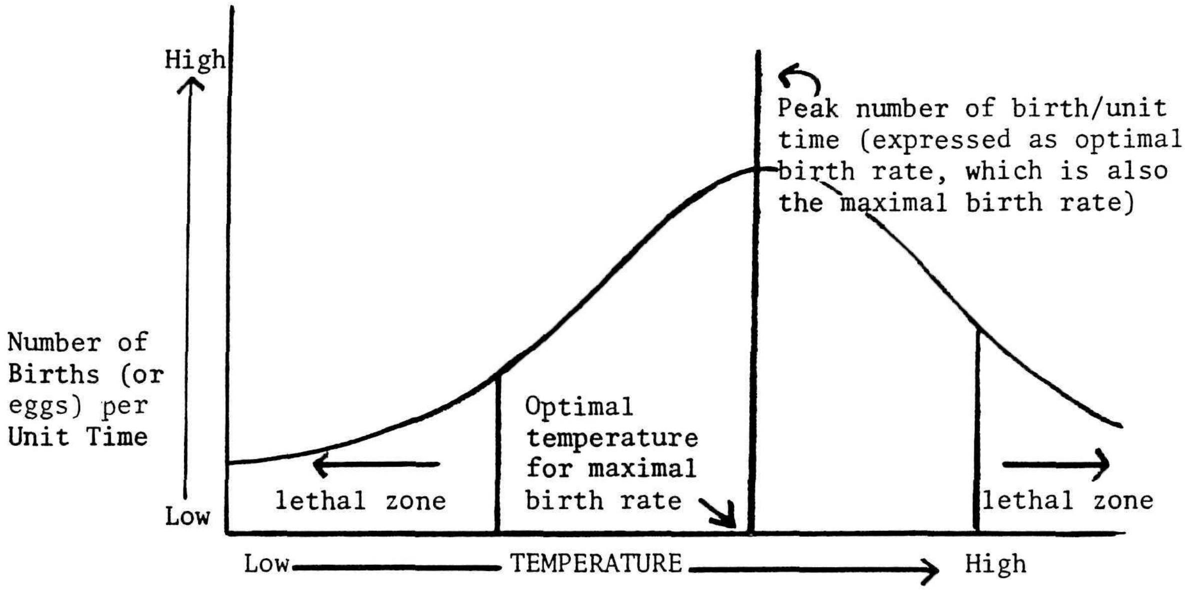
Errors in predicting pest population surges can occur when the manager is unaware of basic life cycle information of the pest and/or its natural enemies, especially the likelihood of these organisms emigrating or immigrating at a particular point in their life cycle. Migrant aphids are a good example. (Other pests such as grasshoppers and leaf hoppers cover large distances as part of their regular behavior rather than as an occasional event in their life cycle.) Leaving out factors 3 and 4 by assuming for discussion purposes that pest and natural enemy migration patterns are not significant leaves factors 1 and 2 as the major sources of potential error in predicting damaging pest numbers.

Weather is the major determining influence on the first two factors above. Its effects on the reproductive rate are more well known. Higher than expected temperatures may either increase or reduce reproductive rates. Figure 10 shows the typical relationship between temperature and population growth. Regular monitoring allows you to withhold treatments when the temperature shows that the birth rate of the pest will be declining, assuming all else is the same. The most difficult predictive situations are presented by multi-generation pests such as aphids which have living young that affect their host plant immediately after birth.

A similar pattern (i.e. with an optimal level) is known and can be expected for natural enemy attack rates. In theory, therefore, one can begin to understand whether a pest/natural enemy system at different temperature can be expected to remain below or exceed injury levels by knowing their optimal reproductive and attack rates. However, in practical terms unless a predictive verified mathematical model is available to make more accurate predictions, estimates based on judgments of field personnel who are familiar with the pest/natural enemy system in specific localities can be relied upon. Actual changes in pest/natural enemy systems are more complicated than simply assessing birth of pests and mortality caused by natural enemies. For example, there are lags to account for by non-feeding stages like eggs, pupae and diapausing stages of both pest and natural enemies.

FIGURE 10

THE EXPECTED PATTERN OF REPRODUCTIVE RATES FOR PEST ORGANISMS IN RELATION TO TEMPERATURE ALONE



Predicting Pest and Natural Enemy Populations from Field Samples

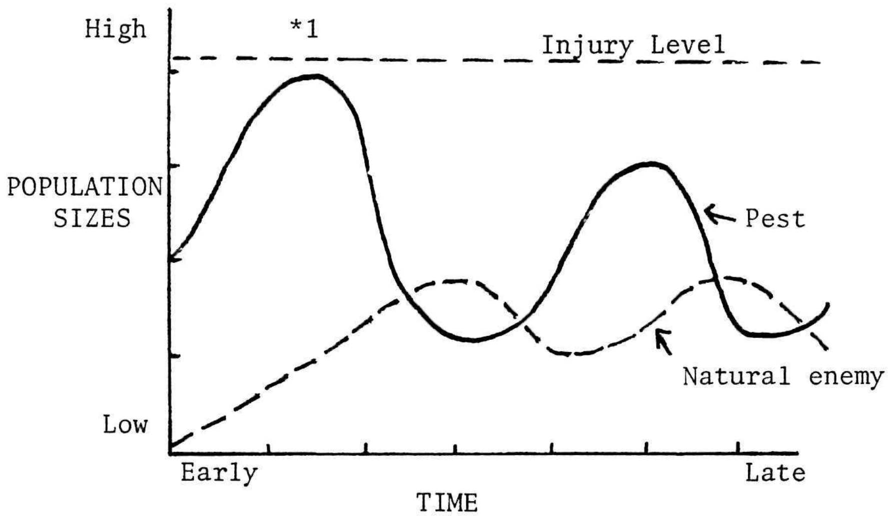
Pest populations only increase or decrease from births, deaths and/or movement into or out of the local area. Predators and parasites may be very important in causing pest mortality. (See "Natural Controls," page 66.) The basic predator/prey or parasitoid/prey relationship is shown in Figure 11. Two common relationships that follow this pattern are the predaceous mite, Phytosieulus persimilis (Acari: Phytoseiulidae), on the twospotted spider mite, Tetranychus urticae (Acari: Tetranychidae), and the hymenopteran parasite, Encarsia formosa, on the greenhouse whitefly, Trialeurodes vaporariorum (Homoptera). Management decisions are made more difficult when the injury level is approached or exceeded close to the time when the natural enemies suppress the pest population.

If the predation or parasitism rates or impacts on the pest are overestimated, and action is delayed, the pest population may rise suddenly (Figure 9). However, what usually happens is that the impact of the natural enemies is underestimated and unnecessary treatments

FIGURE 11

THE PREDATOR-PREY INTERACTION

ILLUSTRATING THE PREDATOR LAG PHENOMENON



*1 Note: pest closely approaches injury level but does not exceed it because of natural enemy induced mortality.

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or premature treatments take place. In the example shown in Figure 11, the pest population was suppressed by one of its natural enemies before it reached the injury level.

The best way to avoid these errors is to collect enough field data to allow you to measure both the pest population growth patterns and those of its natural enemies. To date, insufficient work has been done on these crucial biological relationships; in many geographical areas, almost no data has been collected. Plans for IPM programs must allocate time and resources necessary to conduct applied research on these basic relationships.

DEVELOPING THE PEST MANAGEMENT SYSTEM

IPM STRATEGIES AND TACTICS

The many treatment options available to the pest manager were introduced in Part I, Section III of this manual. The names of the strategy categories into which the tactics are grouped are somewhat arbitrary. Some tactics fit equally well under two or more categories. For example, erecting a barrier against the pest might be referred to as a physical control, habitat management, or in cases where a permanent barrier is built in, part of a design or redesign approach.

Because most IPM work to date has been carried out in agricultural production systems, slightly different groupings have been given by other professionals in the field, for example:

Integrated Pest Management Concepts

Objective	*Characteristic* or use*
Classical biological control	Introduction of preferably host-specific, self-reproducing, density-dependent, host-seeking exotic, natural enemies adapted to an exotic introduced pest, resulting in permanent control
Augmentative or inundative biological control	Mass propagation and periodic release of exotic or native natural enemies that may multiply during the growing season but are not expected to become a permanent part of the ecosystem
Conservative biological control	Management of the biota of the entire agroecosystem to enhance and conserve existing natural populations of native or introduced natural enemies, such as through use of polyculture, strip cropping, and organic soil amendments
Competitive control	Use of innocuous organisms to increase competition for ecological niches occupied by pests. Such organisms may include hypovirulent strains of parasites; genetic or induced pest-resistant, highly competitive crops; sterile male insects' trap plants to divert pests from crops
Biorational control	Use of behavior-modifying compounds such as pheromones, kairomones, repellents, attractants, antifeedants, and food sprays to attract parasites
Chemical control	Use of natural or synthetic compounds that interfere with metabolism, such as herbicides, fungicides, insecticides, hormones, chemosterilants, growth regulators, and microbial toxins
Culture control	Management of the agroecosystem by physical techniques such as quarantine, sanitation, rotation, tillage, cultivation, timing of operations, pruning, irrigation, fertilization, weeding, mowing or grazing, crop isolation, scarecrows, light traps, and reduced row spacing

*These characteristics are not always mutually exclusive. Source: Suzanne W. T. Batra, "Biological Control in Agroecosystems" 8 January 1982 *Science* 215:134–139.

What is more important than how the strategies are grouped or titled is the understanding by the pest manager that all the various tactics can be described as having either of two basic effects on the pest population: direct and indirect. A direct tactic focuses on the pests themselves, for example, through the application of a pesticide or handpicking, etc. Indirect approaches focus on the biophysical or "environmental," and the social or human behavior aspects of the pest problem in an attempt to enhance the effect of natural controls on the pest, to modify human maintenance activities or attitudes, or otherwise modify the life support system of the pest. Attitudes can effect injury levels which in turn can have substantial effects on pest management programs. For example, when people learn that boxelder bugs are not harmful, they often shift from demanding pesticide treatments of the boxelder tree to individually vacuuming up local bug infestations at their doorstep and using screens to keep them from entering the house.

Natural Controls

If birth rate alone were to determine the size of any population of organisms, it would grow infinitely large very quickly. This never happens, of course, because of a number of population suppressing factors, sometimes referred to as "natural controls."

Natural controls upon a population may be summarized as:

- Food, water and habitat availability
- Climate and weather
- Inter-and-intra-specific competition
- Action of predators, parasites and pathogens, or "biological controls"

  Definitions:

  Predator: Free-living, general feeders that, ideally, eat many individual hosts during a meal. Predatory insects in the larval stages require several prey to attain maturity. For example, the well-recognized ladybug, Hippodamia convergens, will skim off the top of abundant pest populations and then move on without providing sufficient direct pest suppression. Adult predators lay their eggs near prey populations where the young, after hatching, search out and consume their prey.

Pathogen: Pathogen, in general, refers to those single-celled, microscopic species that kill or debilitate another species, or a group of closely related species, by inducing disease.

Parasite (or Parasitoid): The distinction between parasitoid and parasite is that the former kill their hosts while the latter do not in all cases. Hence, parasitoids provide more effective pest control. Usually one parasitoid individual develops from a single host and from a single host stage (e.g. egg, larvae, or pupal parasitoids--few attack adults). Thus one can classify parasitoids by: monophagous, obligophagous, or polyphagous for one, a few, or many species attacked; the stage of host attacked; the number emerging from a single host (solitary or gregarious); and as an ecto-or-endoparasitoid (living within or externally on the host).

Multiple parasitism occurs when two or more different parasitoid species develop within a single host from different eggs. A parasitoid developing in a non-parasitic host is a primary parasitoid, whereas a parasitoid developing at the expense of a primary is a secondary parasitoid, also called a hyperparasitoid. Hyperparasitoids, because they attack "beneficial" species, are detrimental. Autoparasitism, a special case of hyperparasitism, occurs when one sex develops as a hyperparasitoid on the other sex. Superparasitism occurs when more eggs are deposited in a single host than can develop because of limited food. This phenomenon can commonly occur in laboratory cultures, but when it occurs in the field it is cause for concern because it may indicate lack of "fit" between host and parasitoid.

Most parasitic larval species, in contrast to predators, do not have to search for their prey. This characteristic provides a key difference between the two ecological categories which is important in assessing their role in population regulation. The time lag introduced by the need to search for prey allows population growth of the host to continue. If the host is a pest, the introduced lag time could translate into increased plant damage and yield losses before the host population is reduced. A parasitic species, however, has no such lag, thus can keep prey populations better regulated than if a predator is the primary mortality agent. The power of the parasitoid therefore resolves to its host-searching and reproductive capabilities. These generalizations and terms should be taken as guidelines since there are many exceptions.
(From: The IPM Practitioner, Vol. 3, No. 6 .)

In general, pest management strategies which act indirectly upon the pest problem through enhancing or mimicking the effects of natural controls may have a more permanent and/or less ecosystem-disruptive impact. To that extent they may be more cost-effective in the long run than direct attempts to kill off the pest through physical or chemical means. At the same time an initial investment of thought and money may be required to achieve suppression through indirect means that is greater than that needed for less subtle but more direct action.

ESTIMATING BENEFITS AND COSTS

Certain benefits are not easily expressed in dollar amounts. One of the major benefits of a habitat management strategy, for example, is the preservation of natural enemies whose value is enormous to the pest manager but hard to calculate monetarily. Another kind of benefit from a design or habitat management strategy is improved public relations. This is also hard to quantify but is obviously highly valued by park managers. Each park's management will need to assess the pros and cons of the various management strategies in accordance with its own interpretation of the prevailing values for the park community.

Each strategy or a combination of strategies will affect the environment surrounding the pest as well as the pest itself. Among the broader values to consider in making a choice of strategies and tactics are their effect on:

- The natural enemies of the pest
- The field operators work conditions
- The diversity of the ecosystem
- The air, soil and water of the surrounding community, in both the near and more distant future

One of the major strategies, Design/redesign, has the advantage of being the most permanent. There are many situations, however, where the pest must remain in the system because removing its host is impossible or prohibitively costly or because it plays an essential role in the ecosystem. In such cases, the next most permanent strategies should be considered.

If the pest population cannot be brought below the injury level by indirect suppression techniques, then direct suppression techniques should be considered, realizing that these provide only temporary solutions and will need to be applied repeatedly (probably at rising costs). A combination of the two approaches may prove to be the most effective solution.

IPM Transition Costs

As discussed above, estimates of the costs of one management strategy versus another may be difficult to make because some are more permanent and more likely to lead to stable local ecosystems than others. In addition, there is a distinct set of costs associated with moving from conventional pest management (CPM) to integrated pest management (IPM): these costs can be called transition costs (TR). There is yet another set of costs associated with running or maintaining IPM programs, these can be called IPM program costs, or IPM costs.

Conventional pest management (CPM) costs are essentially the costs of purchasing and applying chemical pesticides. Transition costs (TR) include the initial training costs and the costs of implementing new strategies and techniques in the first year. IPM costs are the costs of further implementation of new strategies and techniques, including monitoring, plus the costs of running the overall program in the second and subsequent years.

Thus, the first year costs of an IPM program will include both TR costs (covering monitoring and new methods costs) and some CPM costs. The total costs of pest management for that year are likely to be higher than conventional pest management alone would have been, but are not necessarily higher. Usually a substantial reduction in CPM costs is realized in the first year, because unnecessary treatments are identified and suspended.

In the second year costs are reduced: CPM costs are down, and IPM costs are up, but total costs are down. When transition costs end depends on the rate at which the agency staff institutionalizes the technology.

A transition plan may have to be developed with interim strategies used until more permanent changes can be instituted. Any description of the overall IPM program should explain the difference between the transition approach and the eventual goal. Intra-agency meetings, communications, training programs, and budgets will all need to be planned with the fully realized program in mind.

EVALUATION

Evaluation must be made of the program components (i.e. the monitoring system, treatment activities, etc.) as well as the entire program. Some treatments, such as chemical controls, must be evaluated immediately after application and again at regular intervals during the season. Other tactics cannot be expected to show effects for a season or more.

The Integration in Integrated Pest Management

The word "integration" in IPM is usually understood to mean that all possible means to effect the pest population are integrated into a systematic approach to the problem. Integration also means the smooth interaction of all of the above systems to achieve the program's ultimate purpose: a coexistance between humans and the pest organisms that is satisfactory to the people involved (and does not threaten the survival of the immediate environment of which both humans and the pest species are a part).

Because the ecological principles that underlie good pest management are complex and not commonly understood, education and communication often turn out to be the most important tools of the IPM project coordinator in achieving a program rated successful overall.

TREATMENT RECORDS

Once pest suppression tactics are initiated, various forms can be used to record treatment actions, results, and evaluations. Some examples follow.

Sample Forms

Sample Form 8 can be used as a general form to record the application of a pesticide to any bed of flowers or shrubs even though it was first developed for use with the azalea lace bug. A simple form like this one with dates, locations, recorder name, what pesticide was used (generic and trade names; and dosage), equipment used and comments about the pest and natural enemy populations before and after treatment can be developed for each pest problem.

A more complete form (Sample Form 9) includes this and additional information which should also be collected. The additional information includes the amount of labor used during application. This information allows for calculation of total costs of treatments.

The IPM Program Summary Sheet collects information of use in appraising an entire program at a single location or unit on a yearly basis. It provides a useful overview using IPM components. This kind of overview can be useful to determine development possibilities as well as the state of existing developments.

Sample Form 11 is used by program managers in conjunction with other forms (i.e. see #9) to compute the total cost of a treatment or related maintenance activity. Full appraisal of costs and benefits of treatments first require some measurement of the costs of treatments. Thus this information and its subsequent appraisal is vital.

AZALEA LACE BUG TREATMENT RECORD

Date: ______________________________

Park: ______________________________

Recorder: __________________________

Bed: _______________________________

Application:

Rate: ____

Material: ____

Area Treated: ____

Equipment: ____

Comments: ____

____

____

____

____

____

____

____

____

____

____

Pest Monitoring Information (General)

(Note: This form includes space for recording chemical treatments.)

Date: Form Completed By:

Location:

Pest (common name):

Pest Population Size (draw map with numbers observed):

Natural Enemy Sample or Observation

Other Relevant Data Affecting Pest Population

Recommended Method and Time For Treatment:

Type of Treatment (Circle one or more, describe) - mowing, burning, pesticide, other:

If A Pesticide Was Used, Record The Following: (attach label)

Trade Name:

Generic Name:

Amounts Used:
(total amount or solution applied)

Amount of Active Ingredient Used:

Registration Number (EPA):

Equipment Used:

Type: Hours Used:

Labor Used:

Who:

Job Category:

Results of Treatment Upon Pest Population:

Sample Form 10

IPM PROGRAM SUMMARY SHEET

TARGET PEST	MONITORING PROCEDURE	INJURY LEVEL	ACTION LEVEL	TREATMENT	TIMING	EVALUATION

PEST TREATMENT AND MAINTENANCE ACTIVITY EVALUATION RECORD

Inclusive Dates: From: To:

Location: Compiler of form:

Type of Pest Treatment or Maintenance Activity: circle one:
(smoke bomb, mowing, dragging, discing, planting, burning, other)

Activity Description:

a. number of total person hours and wage scales involved.

b. number of separate dates activity occurred.

c. type of material used (e.g., herbicide, gasoline, plants, etc.).

d. amount of material used.

e. equipment used.

f. hours of equipment use.

Total Cost of Activity (estimated):

Subtotal person hours x wage scales = ____________

= ____________

Total = ____________

+ cost of materials = ____________

+ equipment costs = ____________

TOTAL COST OF ACTIVITY ____________

EVALUATING TREATMENTS

QUESTIONS TO ANSWER AT THE END OF THE SEASON

1. Was the pest population adequately suppressed (below injury level)?
2. Was the pest population suppressed in a timely manner?
3. Was the planned procedure used? If not, what was different?
4. Was the cost of suppression equal to or less than the expected damage?
5. What damage was produced? What damage was tolerable?
6. Were natural enemies affected by treatments? How?
7. If natural enemies were killed by treatments, will this cause problems elsewhere or at a later period?
8. Were there any other side effects from the treatments?
9. Were the side effects added to the cost of treatments?
10. If ineffective, should the treatments be repeated?
11. If ineffective, should another kind of treatment be evaluated?
12. Is the plant or structure worth maintaining? Can the site be changed to eliminate or reduce the problem for the same costs of treatment?
13. Was equipment available at the appropriate time?

OVERALL PROGRAM EVALUATION

Successful pest suppression does not necessarily mean that the whole program is a success. Conversely, inability to affect pest populations does not inevitably mean program failure (for example, when the public is educated to accept a different level of abundance of a particular organism). This paradox can be understood by realizing that the management of parks and other urban and suburban sites usually takes place within a highly politicized social environment.

- Public standards regarding manicured, "unblemished" landscapes may be artificially high and conflict with the level of resources available for management, the conservation of the natural landscape, and/or the ecological balance of the system.
- Fear of the pest organism, or its effects, may be greatly exaggerated or totally unfounded.
- Methods used to successfully suppress the pest may affect other parts of the system negatively (for example, by removing the food sources of some desired organism, or increasing competition with it), or may cause adverse human reactions (for example, by arousing public opinion against a tactic employed).

Unanticipated negative responses to the program are often a consequence of focusing too narrowly on one component of the system (commonly the pest and its control). For purposes of overall evaluation, it is helpful to view the IPM program as composed of many simultaneously occurring interacting systems or processes:

- monitoring
- record keeping or field data
- decision making regarding treatment activities
- delivery of treatments
- evaluation of treatments
- collection and cataloging of reference materials or management of the pests
- training of maintenance personnel
- education of agency personnel on IPM
- communication to agency personnel and public regarding program particulars and progress
- budgetary planning
- evaluation of overall IPM program

Each of these components should have, as part of the development of the initial program plan, some expressed objectives or criteria by which the component is judged successful or not. But, in addition, questions must be asked: Were all the necessary components to the program actually developed? Were they integrated successfully? Were the right people involved in the integration of the components into a whole program?

TRANSFERRING THE TECHNOLOGY

Information on the strategies and tactics to be employed and the methods by which they are to be integrated into the ongoing program, must be passed on to others who will be directly or indirectly involved. Some of the information may be totally unfamiliar to the recipients and at times may even appear to be contrary to their current practices. The study of the process of technology transfer in general provides some helpful insights into what might be expected when IPM concepts and techniques are introduced within an agency.

Several stages have been identified in the adoption of innovation.

1. Awareness of the new technology
2. Interest in it
3. Assessment of its utility
4. Trial
5. Implementation
6. Maintenance

Awareness levels may be raised by employing

- Information tools of many types (magazine and newspaper articles, books, papers, lectures, discussion sessions, etc.)
- Information media that is intrinsically interesting (films, slides, cartoons, games, etc.)
- Sustained information delivery (newsletters, regular memos, bulletin boards and displays, study groups, etc.)
- Personal interactions (field trips, one to one informal discussions, etc.).

Awareness alone does not lead to technology adoption, but among people who might be characterized as "early adoptors," interest is aroused.

Interest leads to a desire to learn more about the technology. At this point people want

- In-depth case histories of successful application
- Contact with people who have used the new technology successfully

Assessment by the potential adopter means examining the new technology to see if it appears

- Effective
- Inexpensive
- Flexible (can be tailored to the unique circumstances of the adopter)
- Simple
- Sustainable
- Preferred (preferred among comparable activities or options)
- Compatible (with existing values, past experiences and other needs of potential adopters).

Trial and implementation of the innovation requires that the description of the process to be followed is broken down into the smallest possible steps. Because IPM processes require the modification of behavior according to observed field conditions ("on-line" decision-making), it is often useful to use decision trees (see Example 1) or flow diagrams (Figure 12 and 13) to convey this information.

TRAINING AIDS

Example 1: An Overview of a Pest Management Situation

(A decision/logic sequence)

IS IT A PROBLEM?

- Causing economic hardship, medical problems, or political problems?
- Causing unacceptable personnel workload?
- Displacing desirable species?
- Displacing rare, native species?
- Altering historic scene?

↓YES NO (no action needed)

ACTION NEEDED

- Are possible actions feasible?
- Will action be effective?
- Are actions okay by policy?
- Will actions be environmentally sound?
- Are actions safe to humans?
- Has man's manipulation caused the problem in the first place?

↓YES NO (take no action)

CONSIDER NON-TOXIC ACTION

- Will physical removal or a barrier be used?
- Can traps be used?
- Can natural processes such as succession, predation or biological control be used?
- Can you remove the cause of the problem rather than just treat the problem? (habitat modification)
- Can altered maintenance practices solve the problem? (horticultural controls)
- Can a permanent design change to the environment eliminate the problem?

↓NO YES (take action)

CONSIDER A PESTICIDE

- Is the material delivery system effective under your circumstances?
- Can a bait be used over a broadcast spray?
- Will spot treatment be effective?
- Is the material chosen least toxic to natural enemy populations?
- Is the material chosen least toxic to operators?
- Can it be applied without additional safety equipment?
- Does the material break down rapidly to non-toxic products?

↓NO YES (use it)

RECONSIDER above alternatives again, or take no treatment action except education of staff and public.

FIGURE 12: KEY FOR INTERPRETING PEST MANAGEMENT FLOW DIAGRAMS

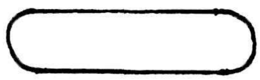
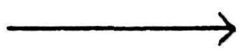
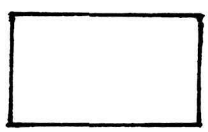
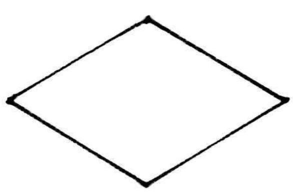
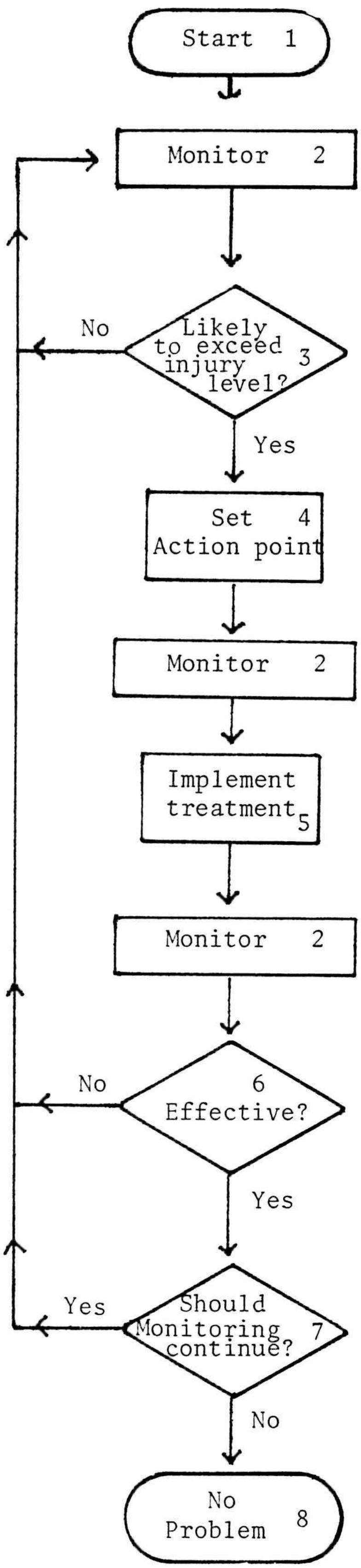
Symbol	Name of Symbol	Explanation
	Terminal	A start or end point in a program
	Arrow	Direction for reading diagram
	Box	Procedure, something to do, a treatment
	Diamond	A question, only 2 answers possible, a "yes" or a "no"

FIGURE 13

A GENERALIZED MANAGEMENT SEQUENCE ALGORITHM



1) Start the pest management process here if pest problem is present or anticipated.

2) Once started, monitoring is a continuous process until "no problem" (7) occurs, then it stops.

3) Will the problem exceed the injury level (within X time)?

4) The action point is the latest point in time when treatment action should be taken to prevent unacceptable injury. The action point is set knowing the treatment tactic planned and the amount of preparation time required.

5) The treatment action takes place if and when the action point is reached.

6) Was the treatment effective? If not, monitoring will continue and retreatment will probably occur. If yes, the problem is resolved.

7) Is there a reason to continue monitoring this season? (Example: more than one generation of pest per year.)

8) Monitoring ends, at least for the season.

MAINTENANCE OR INSTITUTIONALIZATION

Maintaining the new system within the institution once the original designers and coordinators have moved on to other things may be difficult. Institutionalization may require the conscious building in of positive incentives to repeat the new behaviors (or negative incentives to prevent reverting to earlier, familiar patterns) that may be beyond the job authority of the people who realize the necessity for them.

Devices that might be employed include:

- Internal agency recognition
- Public recognition
- Re-writing of job descriptions
- Changes in agency policy
- Restructuring of contract specifications (where outside agencies are involved in delivery of pest management services)

The IPM designer/coordinator should prepare, in written form, a complete description of the program as it should be maintained. Ideally, this should exist in two versions: One for supervisors (this might be in a report form), and one for field personnel (a convenient form is a loose-leaf binder, since materials may be added or deleted over the years.

Developing a Loose-leaf Binder for Field Use

Field people need to know:

- The overall IPM process for managing each pest
- Biological and ecological information on the pest and its natural enemies
- The sampling system for the pest and its natural enemies
- The monitoring system for horticultural and other maintenance activities that indirectly effect the pest
- The record-keeping system to be used
- How to interpret summarized displays of field data
- The tools required in carrying out monitoring and treatment activities, and how to use, obtain and maintain the tools

- The range of treatment tactics desirable for use against the pest and how to employ them
- How to evaluate their performance and the effect of the treatment actions
- Where to get further information

To convey the above information you may wish to use:

- Photographs and slides
- Drawings
- Tables
- Text

In many cases, the basic information can already be found in the literature of USDA Cooperative Extension, textbooks, research papers, etc. Undoubtedly these will require some original text, generated by the IPM coordinator of the specific program, to

- Integrate materials duplicated from other sources
- Simplify, and interpret jargon and scientific terminology
- Relate the general materials to the unique circumstances of the site in which the field people will actually carry out their activities
- Identify the relationship of the recommended activities to agency policy

Handouts, Flyers and Other Formats

In addition to or in place of more extensive loose-leaf binders, one or two page descriptions of the problem and its management may be appropriate. This will depend partly on the target user and partly on the complexity of the problem. In general, shorter materials are suitable for agency personnel not directly related to the field activity and/or the general public. Some examples follow.

THE TULIPTREE APHID

Starting in late spring, a sticky secretion or fine mist may be noted underneath tuliptrees (*Liriodendron tulipifera*). This is the result of the tuliptree aphid (*Illinoia liriodendri*) feeding upon the sap in the leaves. Because the aphids cannot absorb all the sap they ingest, they excrete a large quantity of sugar and water in the form of honeydew, which falls on the leaves and ground underneath the trees. Although large aphid populations may lead to some leaf-drop, neither the aphid nor the honeydew cause any serious damage to the tree.

Honeydew should not be confused with blossom-drip which also occurs on tuliptrees in the spring. Blossom-drip is the naturally occurring fall of nectar from the blossoms which results in large (over 1/4 in. diameter) sticky drops.

Life-cycle and Habits of the Tuliptree Aphid

The tuliptree aphid is native to the eastern United states and was first identified in California (San Jose) in 1974. It has since spread throughout the Bay Area with the tuliptree being its only host. The aphids spend the winter as eggs on the trunk and limbs of the tree and hatch around the time of bud opening in April. The aphid generations that follow do not lay eggs but bear live young (see Figure 1). These individuals are females that can reproduce without mating (parthenogenic). Thus the aphids can multiply very quickly and produce many generations a year. The number of aphids rises rapidly between April and June, but drops significantly in the summer (perhaps due to a rise in temperature or changes in the nutrient content of the leaves). In late summer the population rises again, reaching a second (though smaller) peak in September, but then decreases as the leaves drop in the fall. At this time both male and female aphids are produced. These mate and the female lays eggs on the trunk and limbs that will remain throughout the winter.

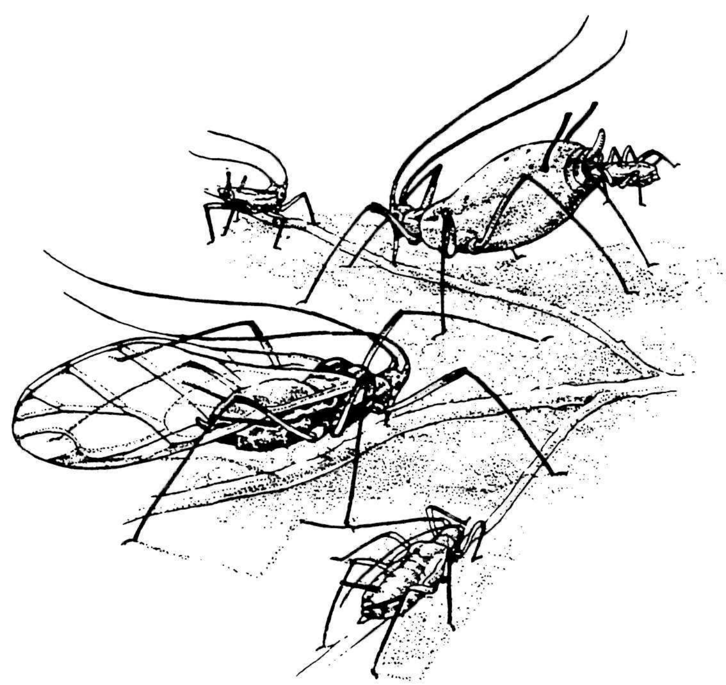


Figure 1 (16×actual size)

Management of the Tuliptree Aphid

In addition to a number of general predators such as ladybeetles and lacewings, there are a few locally-occurring parasitic mini-wasps that attack the tuliptree aphid. Unfortunately these natural enemies are not well-adapted to this exotic aphid and do not always keep the aphid population low enough to avoid excessive honeydew production in the spring.

To alleviate this problem, some form of supplementary treatment is necessary. In the past, heavy reliance was placed on chemical insecticides. However, this approach had numerous drawbacks: 1) Insecticides kill the aphid *and* its natural enemies. Once the natural enemies are killed, the remaining aphids can reproduce faster, thus causing a worse problem in the long run. 2) Repeated applications of the same insecticide often leads to the pest becoming resistant to that material, rendering it useless. 3) Pesticides pose a serious threat to human health, as well as a danger to pets, birds and other animals.

As an alternative, we recommend water-washing. Washing does two things: 1) Kills the aphids directly by the physical impact of the high-pressure water-stream, and 2) washes the accumulated honeydew off the tree. Although a few natural enemies may be killed also, a greater proportion of them are left alive to attack the remaining aphids.

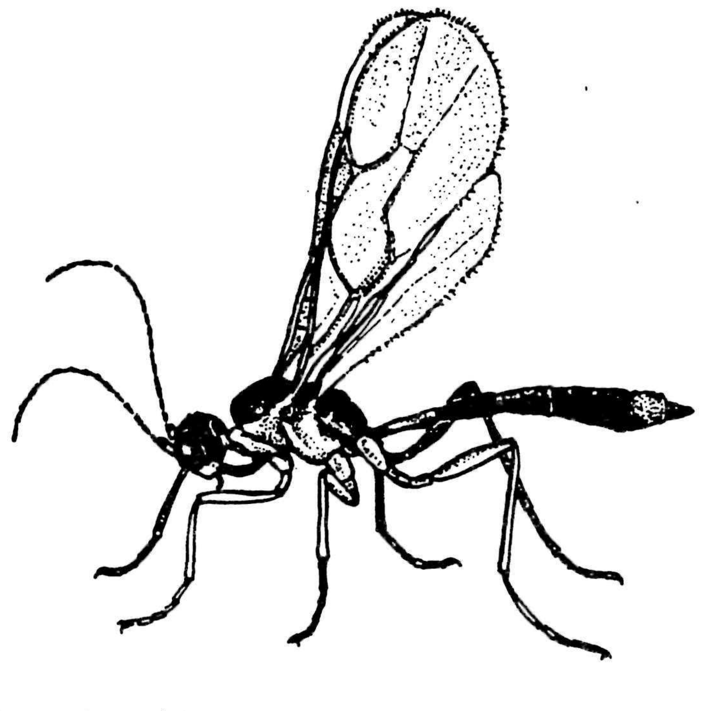


Figure 2 (32 × actual size)

Long-term Control Plans

No matter how effective water-washing may be, we regard it as a temporary measure. In the Eastern United States additional natural enemies of the tuliptree aphid exist. We are presently engaged in a program of importing one of these beneficial insects, a parasitic mini-wasp (*Aphidius liriodendrii;* see Figure 2). This insect attacks only the tuliptree aphid and will not attack anything else. If it can adapt to the climate and environmental conditions in northern California, it could lead to a permanent suppression of the tuliptree aphid population.

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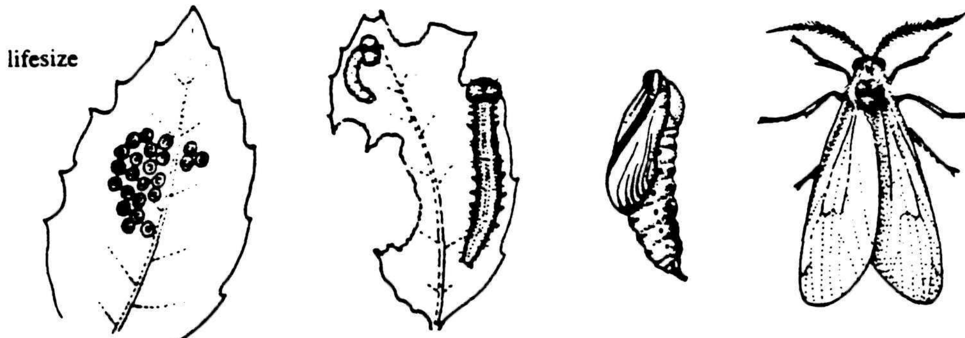
THE CALIFORNIA OAK MOTH

(*Phryganidia californica* Packard)



An Integrated Pest Management Approach

A Sampling Program

The California oak moth population reaches damaging proportions every 3–7 years. The outbreak can last 2–3 years. The basic tool in an IPM program is the periodic sampling and recording of the insect population (monitoring) to see if it has reached a level called the aesthetic injury level, where a large amount of unsightly damage will occur. Monitoring also provides information on the presence of natural enemies. Since the oak moth does not reach the injury level every year, a monitoring program has been developed to avoid unnecessary insecticide treatments. Inspect your tree for larvae during April and again in August. If you cannot do this, ask your local tree company that provides a monitoring service for help.

To sample, examine 25 shoots selected at random around the tree, remembering that the eggs are laid mainly on the upper portion of the tree. This can be done either by climbing the tree or with a pole pruner if the trees are large. The larvae feed close to where they have hatched unless a crowded situation causes them to migrate to other locations. If you find fewer than 8–10 caterpillars on these 25 shoots, it is unlikely that the tree will have serious leaf damage. If there are more than 8–10 present, it may be desirable to treat the tree. (8 to 10 larvae per 25 shoots is considered the Aesthetic Injury Level for this pest on oak in California.)

Biological Facts

- Eggs are laid in clusters during June and again in November on the leaf underside.
- When full grown, the larvae measure 1¼". Their heads are brown or reddish, their bodies green, with black and yellow stripes running lengthwise on their backs and sides.
- Larval feeding occurs intermittently during warm winter periods from November to May, although mainly April–May and again in July–August.
- Young larvae eat the underleaf surface, older larvae consume the entire leaf; both prefer succulent foliage.
- Pupae are found on trunk, limbs, branches and undersides of leaves.
- Adult moths *do not feed*, and therefore cause no damage.
- Adult flights occur in June, and October–November.
- Two generations per year, one nine-month fall to spring generation, one three-month summer generation.
- Range: Central America and Mexico, coastal California from the southern border north to Santa Rosa.

Host Preference:

- Coast Live Oak, *Quercus agrifolia*
  Valley Oak, *Quercus lobata*
  Holly Oak, *Quercus ilex*

Cultural Controls

Keeping your oak tree healthy is where primary tree care effort should be placed. This means providing it with the environmental conditions it requires, in addition to regular maintenance such as pruning and fertilizing. While oaks vary in their need for water, the valley and coast live oaks have evolved in the areas of California that do not receive summer rain. Because of this, in their native setting oaks send down deep roots to tap available ground water. Planting lawns and other water-loving plants within the dripline encourages the tree to root at the ground surface. This makes the tree unstable in harsh weather and the constant surface moisture is an excellent way for fungi such as oak root fungus (*Armillaria mellea*) to infect the tree. Withdrawing your oak from summer surface water must be done slowly over a number of years. Remove all water-loving plants from within the dripline, then mulch the ground around your oak (out to the dripline) to keep in normal moisture and allow air to circulate among the roots. Soil aeration is critical for maintaining tree health. Deciduous oaks provide their own mulch and over time leafdrop from evergreen oaks will create a protective environment and add nutrients to the soil. For healthy, well-foliated trees, insect feeding acts like normal pruning. A declining or "thin" tree may not be so able to withstand such feeding. Efforts should be made to decrease any additional stress on such weakened trees.

BIOLOGICAL CONTROL

The oak moth population is kept under control by a variety of factors, the most important of which is harsh winter weather. Other limiting factors are depletion of food supply, insect parasites, predators, fungus and virus diseases. Of the known oak moth parasites, two mini-wasps, *Itoplectis behrensii* and *Brachymeria ovata*, provide the greatest control.

Biological Facts

Itoplectis behrensii (Cresson)
(Hymenoptera, Family Ichneumonidae)

- This pupal paraiste is at times the most prevalent and effective control of the oak moth parasites, responsible for up to 90% mortality.
- It is synchronized with and specific to the oak moth.
- One parasite generation is produced each oak moth generation.
- It prefers the trunk area pupae but will parasitize foliage pupae, and lays a single egg per pupa.
- Mating occurs near the tree and the adult parasite is present throughout the oak moth pupal stage.
- It is easily killed by pesticide treatments, particularly carbaryl (Sevin®), but is not harmed by *Bacillus thuringiensis*.
- This parasite has not been found north of Marin County.

Itoplectis behrensii

Brachymeria ovata

lifesize

Brachymeria ovata (Say)
(Hymenoptera, Family Chalcididae)

- This pupal parasite is responsible for approximately 10% of the parasite control.
- It is not synchronized with the oak moth and has as many as 100 alternative pupal hosts among the butterflies and moths.
- Two or more generations are produced each oak moth generation.
- It prefers to search the foliage for pupae and lays a single egg per pupa.
- It is also easily killed by pesticide treatments.

Other Natural Controls

The predatory bug, *Podisus maculiventris*, and two fly parasites, *Actia flavipes* and *Zenillia virillis* contribute to control. When oak moth populations are high they are sometimes dramatically reduced by a nuclear polyhedrosis virus disease.

MICROBIAL CONTROL

In outbreak years local populations of oak moth may grow large enough to cause widespread defoliation. While healthy live oak trees will not be killed by this leaf loss, the damage may be distressing to those who dislike the look of the tree, or are disturbed by the presence of oak moth larvae.

The best way to control the oak moth is by spraying the trees with a naturally occurring disease of these caterpillars, *Bacillus thuringiensis* (*B.t.*). This material is harmless to people, their pets and other domestic animals. It also offers great advantages over other pesticides because it will not harm bees and other beneficial insects such as the predators and parasites that keep pest insect populations under control. Timing of treatment is an important factor with *B.t.* for it must be applied when larvae will eat the spores. The larvae die within 4–10 days. It is important that some oak moth larvae remain alive as food for their natural enemies to help bring the population back into ecological balance quickly. The purpose of using *B.t.* is not to eradicate the oak moth, but to reduce population levels on the tree to one that is tolerable.

Presently there are two approaches to *B.t.* application. Both are preceded by sampling. The first is done in mid-March when the larvae are ¼" or longer. If the larval count exceeds the injury level, moderate damage can be expected. If this is intolerable, *B.t.* can be applied at a dosage 0.25–0.5% two to three weeks later when the third instar (1 inch or more) larvae are first seen feeding on the leaf edges. This approach has been most comonly used to date.

The second involves sampling eggs and newly hatched first instar larvae in June and November. This approach is based on the fact that first instar larvae feed exclusively on the leaf under-surface where *B.t.* is shown to have an average half-life* of thirty days, as opposed to a one-half day half-life on the leaf uppersurface. The amount of *B.t.* that kills the first instar larvae is less than that for third instar, so a lower dosage of 0.001–0.05% is recommended. Two other advantages to this approach are less foliage damage and the cost savings of using less *B.t.* The disadvantage is that mortality due to predators and disease over the winter cannot be predicted and treatment may occur unnecessarily.

Bacillus thuringiensis is available under several trade names, Thuricide,® Biotrol® and Dipel® Purchase in wettable powder form and make sure the pH of your water is neutral. Further directions for use will come with the product. This material must be stored in a cool dark place to remain effective. Be sure that the tank and lines used for this spray have been cleaned out, so that no residues of other insecticides or herbicides remain.

*Half-life is the time it takes for half of the material to break down.

This handout has been especially prepared with Sohner Tree Service by the Center for the Integration of the Applied Sciences (CIAS), a project of the John Muir Institute for Environmental Studies. A list of the Center's publications can be obtained by writing to CIAS, 1307 Acton Street, Berkeley, CA 94706, (415) 524-8404.

THE FALL WEBWORM

From July to September you may notice large webs in a number of trees, marking infestations of the fall webworm (*Hyphantria cunea*). In the Bay Area they occur predominantly on sweetgum (*Liquidambar styraciflua*) and to a lesser extent on mulberry (*Morus* spp.), walnut (*Juglans* spp.) and elm (*Ulmus* spp.). The webworm has never been known to seriously harm an ornamental tree since the foliage they feed upon grows back in the following year. However, the webs that the caterpillars construct for protection and feeding purposes are regarded by many as unsightly, and some people can be upset by the presence of caterpillars leaving the trees in the fall.

Life-cycle and Habits of the Fall Webworm

The webworm is probably native to the southeastern area of the United States, but has spread and is now common throughout the country. It may have up to four generations each year, but in northern California there is only one, spending the winter as a pupa. In the spring the adult moths emerge from their cocoons, fly and mate. Eggs are then laid in masses on the underside of leaves. Since the moths are active only at night and the eggs are small and hard to see, the webworm is usually not noticed until the eggs hatch in July and the caterpillars (larvae) begin to build their webs. The webworm favors the light and usually build their webs on the sunnier side of the tree. The caterpillars feed on the leaves in the web, and enlarge the web as they deplete their food supply. The larvae stay feeding in the web until late August or September. Then they leave the web, crawl down the trunk of the tree and search for a sheltered site to pupate and spend the winter.

Larvae are ½ actual size. Web may be several feet long.

Natural Enemies and Management of the Fall Webworm

There are at least four species of parasites which attack this exotic caterpillar in California. One is a mini-wasp of the family Ichneumonidae. The other three are flies belonging to the family Tachinidae. All four attack the larvae of the webworm, but only in low numbers.

Since the fall webworm causes no serious damage to the trees, treatments are seldom, if ever, necessary. However, if the sight of the webs becomes bothersome, they can be managed in several ways. The first is to clip off the branch with the web on it and then destroy the caterpillars either by burning or shredding the web, or by placing the web in a sealed plastic bag and leaving it in the sun for a day or two. If you can't reach the branch to clip the web, you may be able to wind a long pole (with several nails in one end) through the web to destroy it. Finally, if you desire to spray the web, you can use a substance called *Bacillus thuringiensis* (*B.t.*) (trade names: Dipel[R], Thuricide[R], or Biotrol[R]). *B.t.* is a naturally occurring bacteria that is specific to caterpillars and will not harm people, pets, birds or beneficial insects. In order for *B.t.* to work, the caterpillars need to ingest the spray, so treating caterpillars as they crawl down the trees in fall will not work since they have finished feeding by that time.

Biological Control of the Fall Webworm

We are now studying the life cycle and natural enemies of the webworm in the Bay Area. We hope eventually to be able to import more efficient natural enemies from the webworm's native area and release them in California. In the meantime, chemical insecticides should be avoided since they will kill the few parasites already here. Repeated use of the same material may also lead to resistance in a pest species, making the material eventually useless. In addition, pesticides can pose a serious health threat to people and animals, both by acute poisoning, as well as by long-terms effects (including cancer, birth defects and genetic mutations).

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SUMMARY

This booklet has described the concept of Integrated Pest Management as it could be applied in the National Park Service. Specific suggestions, examples and explanations are provided to introduce personnel to IPM program components. We would greatly appreciate getting readers' responses to the content of this booklet, including notice of errors, mis-statements, new concepts, and new examples.