Mosquitoes

This module is intended to serve as a source of basic information needed to implement an integrated pest management program for mosquitoes. Any pest management plan or activity must be formulated within the framework of the management zones where it will be implemented. Full consideration must be given to threatened and endangered species, natural and cultural resources, human health and safety, and the legal mandates of the individual parks. Recommendations in this module must be evaluated and applied in relation to these broader considerations.

While mosquitoes remain a major killer in other parts of the world, in the United States, mosquitoes are not the scourge they once were. But they're still irritating, they still bite us, and there are some species in the United States that spread disease. Mosquitoes also serve a vital ecological function. The larvae, pupae, and adults are important as food for fish, birds, bats, frogs, and insects- -an essential consideration when the subject of mosquito control arises in a national park.

The one thing that all mosquitoes require to complete their life cycle is water. If people could manage all standing water, we could manage mosquitoes. While we can fill in a puddle, we don't want to fill in a salt marsh. We can empty a bucket, but it's not so easy to empty a tire dump.

BIOLOGY AND IDENTIFICATION OF MOSQUITOES

Pest Species of Mosquitoes

While there are more than 13 genera of mosquitoes in the United States, most pest mosquitoes belong to one of three: *Aedes*, *Culex* , or *Anopheles*. See Figure 1 for drawings of the life stages of these three species.

Aedes

Some *Aedes* mosquitoes are called "floodwater mosquitoes" because they lay their eggs singly on damp soil or vegetation in areas that are periodically wet. The eggs can remain dormant until they are flooded and conditions are favorable for hatching. Salt marsh species breed in coastal marshes that are occasionally flooded by high tides. Many floodwater and salt marsh species can fly great distances (5 to 20 miles) from their hatch site.

Other *Aedes* species prefer to lay their eggs in artificial containers or tree holes. Again the eggs are laid just above the water line and hatch once they are inundated.

The Asian tiger mosquito, *Aedes albopictus*, first appeared in the United States in 1985. Its rapid spread is of concern because it is known as a disease-carrying mosquito in its

native Asia. It also breeds readily in water-filled containers, so breeding sites are commonly available.

Culex

These mosquitoes breed in quiet standing water of all types, ranging from containers to larger pools. *Culex* species prefer polluted standing water with a large amount of organic material. Eggs are laid on the surface of the water in "rafts," usually of 100 or more eggs. While *Aedes* and *Anopheles* mosquitoes have a pointed tip at the end of the abdomen, *Culex* mosquitoes have a blunt tip.

Anopheles

Anopheles mosquitoes breed in permanent bodies of fresh water. They prefer water with abundant aquatic plants that provide protection from fish and other predators. Eggs, supported by floats on each side, are laid singly on the surface of the water.

Anopheles mosquitoes can be distinguished from *Aedes* and *Culex* mosquitoes in several ways: (1) Anopheles have patterned wings, (2) adult *Anopheles* females have palps that are almost as long as their proboscis, (3) adults rest on surfaces with their head lower than the abdomen while *Aedes* and *Culex* species rest with the head and abdomen parallel to the surface, and (4) the *Anopheles* larvae float parallel to the water surface rather than hanging down at an angle.

Life Cycle

Of the four life stages of the mosquito--egg, larva, pupa, and adult--the adult is the only stage that doesn't exist in standing water.

The female mosquito lays her eggs on the water or, in the case of *Aedes* mosquitoes, above the water in areas that are sheltered from waves and with sufficient organic matter to feed the larvae. Eggs laid on the water's surface hatch in one to three days. Eggs laid by *Aedes* mosquitoes above the water line remain dormant until they are flooded.

The larvae or "wigglers" that hatch must live in water to survive. They float at the surface breathing through an air tube and filtering food material through their mouth brushes. When disturbed, they dive towards the bottom with a jerking motion. The larval stage lasts from five days to several weeks depending on the species and on environmental conditions such as water temperature.

The larvae transform into pupae or "tumblers." Although the pupae don't feed, they are quite active and may be seen breathing at the surface or bobbing through the water. Inside the pupal skin, the adult mosquito is developing and will emerge in two to three days. Mosquitoes pass the winter either in the egg stage or as adults.

Feeding Habits

Only the female mosquito sucks blood, which she needs to lay eggs. Adult male

mosquitoes feed only on plant nectar and are harmless to people.

Most mosquitoes feed just after dark and again just before daylight. They spend the daylight hours resting in dark, damp areas. Some mosquito species, however, feed during the day and others may feed during both day and night.

This blood-sucking habit is what causes certain species of mosquitoes to be disease vectors. If a female mosquito sucks blood from a person infected with malaria, for instance, the disease organisms survive and reproduce in the mosquito, ending up in her salivary glands. When she next feeds on a host, she inoculates her new victim with the disease.

Larval mosquitoes feed on organic debris (with the exception of a few species that are predators). They use a pair of mouth brushes to strain out small aquatic organisms and particles of plant and animal material present in the water.

Seasonal Abundance

Mosquitoes may breed and develop any time from the beginning of spring to the first hard frost of fall. In general, populations are highest in summer and early fall. There may be from one to several generations of mosquitoes during a season depending on the species, the temperature, and the amount of rainfall.

When rainfall is abundant, many species can lay eggs continuously. Under ideal conditions with high temperatures, development can be completed in less than a week, resulting in large populations of flying adults.

Medical Importance

Worldwide, mosquitoes transmit many debilitating and fatal diseases, especially in tropical, developing countries. The most important of these is malaria, which has been on the increase in the last decade. In the United States, mosquitoes are primarily an annoyance, causing itching bites and welts that can become secondarily infected. Human mosquito-transmitted diseases remain relatively rare, due largely to modern pest control methods and disease detection. Encephalitis, among humans, and dog heartworm, among dogs, are the main diseases transmitted in the United States

Encephalitis. At least six types of mosquito-transmitted encephalitis occur in the United States. These are eastern equine encephalitis, western equine encephalitis, California encephalitis, St. Louis encephalitis, Venezuelan equine encephalitis, and La Crosse encephalitis. Each type is caused by a different virus or virus complex affecting the central nervous system. These viruses are normally transmitted by mosquitoes from birds or small mammals. Occasionally horses or humans are infected. Despite the small number of people infected annually by eastern equine encephalitis, it is considered a serious disease because it is often fatal.

Dog heartworm. This is a filarial parasitic disease transmitted by a number of different

mosquitoes to dogs and, rarely, man. Once a problem only in coastal areas, dog heartworm is now found in every state in the United States. The nematodes, which lodge and grow in the heart tissue, can be fatal to dogs if left untreated.

There has been some concern about whether mosquitoes are capable of transmitting AIDS from an infected person to an uninfected person. Unlike encephalitis viruses and other mosquito-transmitted diseases, the HIV virus that causes AIDS is not able to survive inside the body of the mosquito. It has never been proved, and researchers say it's virtually impossible that a mosquito could transmit AIDS.

MONITORING AND THRESHOLDS

Introduction

Sampling and counting the mosquito population accomplishes a number of things. It helps determine whether mosquito control is necessary. It determines what growth stage the mosquitoes are in, providing information necessary to time control methods. It tells which mosquito species are present, especially important in areas of disease outbreaks. Finally, it helps to gauge how effective control efforts have been and when they need to be employed again.

Sampling should be done at least once a week, and more often during peak season. It is important to consistently sample the same sites each time. The numbers counted, the growth stage, and the species and sex should be needed when possible. All of this information gives an estimate of the population and must be compared with previous counts to determine whether the number of mosquitoes are increasing or decreasing.

A park manager can get an estimate of the number of mosquitoes in an area by counts of larvae or adults or both.

Larval Dipper Counts

Larval dippers can be purchased through biological supply houses or you can make your own. It is basically a shallow, plastic, enamel, or aluminum cup attached to a long handle. To collect floating mosquito larvae and pupae, depress one end of the dipper under the surface and quickly but smoothly scoop up larvae. If you move too quickly or cast a shadow on the surface, they will dive to the bottom.

The number of dips at each site will vary according to the size of the water body, but generally are in multiples of ten. Take five dips from open water and five from the water's edge, near vegetation if possible. Dipper inspections should be made weekly during the breeding season. Larvae can also breed in rainwater that has collected in containers such as buckets, garbage cans, canoes, tires, and animal watering troughs. To sample larvae in less accessible areas such as tree holes, use a large basting syringe to collect them. Empty them into a white pan for counting.

One advantage to sampling larvae is that the problem can be treated at the same time it is identified. When counting adult mosquitoes, the mosquitoes can be flying in from some distance away.

Adult Trapping

Trapping of adult mosquitoes gives information on the relative population size and the species composition.

Light traps are useful for monitoring certain species of mosquitoes. Not all species are attracted to lights. Different models of traps vary in the numbers, the species, and the proportion of males to females that they catch.

New Jersey light traps and CDC light traps (and their variations) are the traps most commonly used. Light traps are operated from dusk to dawn, powered either by electric line or a battery. Some traps are available with a photoelectric cell that turns the light on at dusk and off at dawn. When mosquitoes approach the light, they are blown by a small fan down through a funnel into a killing bag or jar.

The light trap should be hung about 6' off the ground in an open area near trees or shrubs but away from competing lights and buildings. Traps should be emptied each morning and the catch stored in a labeled box until it can be sorted and identified.

Since mosquitoes are attracted to carbon dioxide in the host's breath, some light traps are augmented with a one pound block of dry ice, wrapped in newspaper and hung next to the trap. The addition of dry ice also allows sampling on moonlit nights or in areas where bright lights may conflict with the light trap. And it allows daytime sampling of species that are active during the day or that are not attracted to lights.

Because some species are not attracted to light traps, they should be used in conjunction with other kinds of sampling methods. Monitoring for adult mosquitoes is an important part of the management of some mosquito-vectored diseases such as eastern equine encephalitis. The decision to use pesticides for mosquito supression is made only after intensive monitoring of the mosquito population in an area to determine if the species that vectors the disease to humans is present. The incidence of the disease in the wild animal population is monitored as a way to estimate the possibility of transmission to humans. Visitor education is also emphasized to alert people to the presence of the disease and how to go about protecting themselves.

Adult Landing/Biting Counts

Collecting mosquitoes as they land to bite is a convenient method of sampling biting populations. It involves rolling up a sleeve or pants leg and sitting quietly for a designated period of time, usually 10 minutes. During that time, each mosquito that lands on the leg or arm is collected with a battery or mouth-operated aspirator. It is important that you collect the landing mosquitoes for counting and identification and to ensure that

you don't count the same individual again. Biting counts are best conducted from 30 minutes before sunset to 30 minutes after sunset (unless sampling day-biting species) by the same person each time.

The advantage to using landing counts as a sampling device is that you are counting only **biting** mosquitoes. The method does not collect male mosquitoes or species that do not actively bite people. It can also be used to count and collect daytime biters.

When sampling adult mosquitoes, sample all areas where mosquitoes may be a nuisance. Sample areas from which you have received complaints and near areas with high larval or pupal counts. Sample the same sites regularly, from one to seven nights a week. Adult mosquito information is most useful in gauging the extent of the mosquito problem, since it is the adults which transmit disease or create a nuisance.

Threshold/Action Population Level
The data from sampling and monitoring will be used to help decide at which infestation level to initiate management tactics. This decision level will be based on larval and adult counts, complaints from visitors, the potential for disease outbreaks, and the risk of the management tactics to other animals. For instance, in an area where there have been encephalitis cases, the risk is higher and the action level will be lower than in other areas.

The number and location of visitor or neighbor complaints should be plotted on a graph against the counts of immatures and adults for the same date and site. The amount of unacceptable complaints is the injury level. The graph should show the number of mosquitoes that correspond to the complaint injury level. This is the action level.

Action levels are different for each situation. In some areas, general annoyance does not occur until the number of female mosquitoes caught in light traps exceeds 25 per night. Other action levels that have been used are landing rates averaging more than 5 mosquitoes in 10 minutes and dipper counts averaging 5 larvae per dip. However, in most National Park Service locations, the action level would be higher than in a suburban neighborhood.

NON-CHEMICAL CONTROL OF MOSQUITOES

Introduction

The key factor in a mosquito integrated pest management program is determining whether or not control is necessary. This decision requires a regular mosquito sampling program to determine what species are present and in what numbers, and a set of action thresholds to determine if management tactics are necessary. If control is needed, then decisions have to be made on the best combination of tactics to suppress the mosquito population while affecting the environment as little as possible.

Normally, source reduction--eliminating or altering the water so that the mosquitoes cannot breed or complete their life cycle--is the first choice for control. If source

reduction is impossible or incomplete, the next tactic to consider should be biological control of the larvae with predators, bacterial insecticides, or growth regulators. Visitor education also represents an essential part of a mosquito integrated pest management program at national parks. Interpretive displays can be used to explain the role of mosquitoes as a food source for animals such as bats, birds, and fish, and to help visitors understand that not all mosquitoes bite or carry disease. Personal protection through the use of proper clothing and repellents can be explained, as well as the avoidance of areas with high mosquito populations.

Source Reduction

The simple fact that all mosquito species require water to develop is the key to their control. No standing water means no mosquitoes. Source reduction is the first step in an integrated pest management program for mosquitoes. It is simply the use of mechanical methods to eliminate standing water. Source reduction involves filling, deepening, draining, ditching, managing water levels, maintaining shorelines, managing aquatic and inundated vegetation, and others. While these methods may prove to be more extensive and more expensive than some other controls, in most cases they need be done only once. Unfortunately, these methods will most likely require permitting from several agencies before they can be implemented. They are also not feasible in natural zones of a park.

Source reduction controls the immature mosquito stages--eggs, larvae, and pupae. Because these stages are concentrated in discreet bodies of water, they are much easier to control than are dispersed adult mosquitoes. Two water management tactics are ditching and ponding. That these would only be allowed in a developed zone. Ditching controls mosquitoes in two ways. In some cases water drains out of the potential breeding sites. In others, ditching allows fish access to the isolated pools where they prey upon the larvae and pupae. Ponding is another water management tactic that turns a temporary pool breeding mosquitoes into a permanent one capable of supporting fish and other mosquito predators. Ponding is accomplished by raising the water level, digging new pools, or through impoundment.

If standing water can't be eliminated, control of mosquito larvae in the water is the next step. This is best done with natural controls such as mosquitofish or biorational insecticides. The latter do not affect pupae and should not be used if this is the predominant life stage.

Biological Controls

Mosquito-Eating Fish

Fish are the most important predator of mosquito immatures. Mosquitoes are rarely a problem in a body of water that also contains fish. To use fish as a biocontrol agent the water must be deep enough and must have the right combination of environmental conditions to sustain fish. Introduced fish must have protection from native fish and other aquatic predators. The mosquitofish, *Gambusia affinis*, is often reared and released to

control mosquitoes. However, this fish tends to outcompete native fish if not managed with care.

Bacterial Insecticides

Various commercial products containing *Bacillus thuringiensis* israelensis (*B.t.i.*) are available for treating bodies of water. This bacteria kills mosquito and blackfly larvae. It is nonhazardous to humans, other animals, fish, and predacious insects. *B.t.i.* is available as granules, slow release briquettes, or wettable powder. It can be applied by hand, with a backpack blower or granule spreader, or by aircraft.

Because the released bacterial spores must be ingested by the larvae, *B.t.i.* is not effective against eggs, pupae (which do not feed), or mature larvae that are ready to pupate and have stopped feeding.

Natural Enemies

Mosquito larvae are an important food for aquatic organisms. Large numbers fall prey to fish, insects, and spiders. Naturally-occurring bacteria, protozoa, fungi, and nematodes also kill mosquito larvae. Both bacteria and predatory fish have been used as biocontrol agents to control mosquito larvae. Adult mosquitoes are fed upon by birds, bats, frogs, lizards, spiders, and insects.

Other Controls

Screening of doors, windows, and vents is a time-honored method of keeping mosquitoes out of structures. Ordinary window screen of 16 x 16 or 14 x 18 meshes to the inch will keep out most mosquitoes. Campers can hang mosquito netting over cots, tent openings, picnic tables, etc. Long sleeves, long pants, hats, and veils give additional protection from mosquitoes.

Insect electrocuters, or "bug zappers," do not effectively control mosquitoes. Many mosquitoes are not attracted to the light. Tests in residential areas have shown that only a tiny percentage (usually less than 3%) of the insects killed are mosquitoes. Most are harmless gnats, moths, and beetles.

CHEMICAL CONTROL OF MOSQUITOES

Growth Regulators

Insect growth regulators such as methoprene do not kill the larvae but prevent them from developing into adults. Timing of application is important since only mature larvae are affected. Larvae that have already pupated will continue to develop into biting mosquitoes. Methoprene can be applied as slow-release briquettes, granulars, or ground

or aerial spray. Most insect growth regulators do not harm other nontarget species.

Since methoprene does not kill the immatures, you will still collect larvae and pupae in dip counts. The only way to determine whether the treatment was effective is to rear the collected larvae and pupae and observe whether they develop into adults.

Larvaciding

Petroleum oils or specialized mineral oils can be applied to the water. The oil forms a thin film over the surface which suffocates eggs, larvae, and pupae. In the presence of wind, waves, or rain, the oil film breaks up and is less effective. Some oils are toxic to fish, other organisms, and aquatic plants. Various insecticides can be applied to the water as dusts, granulars, wettable powders, or emulsions. Consult your regional Integrated Pest Management Coordinator for specific recommendations for your area. Pesticides will likely kill other aquatic insects and may be harmful to fish, birds, and mammals.

Adulticiding

Adulticiding is space spraying for adult mosquitoes with insecticides. With an effective source reduction and larviciding program, adulticiding should not be necessary. It is generally the last resort in an integrated mosquito control program, since spraying of adult mosquitoes provides only temporary relief. It must be repeated frequently to intercept new mosquitoes moving into the area. Adulticiding may be the only feasible management strategy in a natural area where mosquitoes pose a public health risk, since source reduction is prohibited.

Most adulticiding is accomplished with a truck-mounted, ultra-low volume sprayer. Depending on the size of the area to be controlled, other application methods include backpack or power sprayer, mist blower, thermal fogger, or application from aircraft. Spraying is usually done in early evening when winds are less than 6 mph. Ground spraying is not possible in most natural areas.

Insect repellents

Personal insect repellents containing DEET applied to skin or clothing provide protection from biting. Another repellent, permethrin, may be used on clothing only. Jackets and tents impregnated with repellents are also available.