PROBES

Mosquitoes of Idaho

An Introductory Guide to Understanding Them, Their Importance, and the Control Process

by Donald R. Brothers

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Preface

The purpose of this guide is to introduce the reader to the mosquitoes of Idaho. Mosquito abatement districts, health agencies, extension service personnel and others may find the information useful when dealing with these insects.

This guide is not an entomological treatise and, therefore, its scholastic value is limited. However, since the amount of information pertaining to mosquitoes and their control is so enormous, a few references are provided so the reader may obtain additional information on specific subjects.

Technical terminology has been kept to a minimum, except in two specific areas. Scientific names are necessary to avoid confusing the mosquito species, particularly since most mosquitoes do not have common names. In the identification portion of this guide, some technical terms and descriptions are unavoidable. These are defined and illustrated as necessary.

In addition to the publications consulted, I have relied on personal experience involving mosquitoes and their control, some field data, and a personal reference collection of mosquitoes. Drawings and photographs are my own or as otherwise specified. Some photographs have been computer enhanced and/or staged for illustrative purposes.

Reference to specific equipment, insecticides and suppliers does not necessarily constitute an endorsement, but serves as an example.

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Donald R. Brothers
June, 2003

1

Introduction

Mosquitoes are familiar to everyone. They are small, delicate flies with wings, antennae, long legs and a "beak" or proboscis. The attraction of mosquitoes to humans for feeding purposes is a distinctive characteristic which individuals recognize at an early age. In total darkness, most individuals can identify a mosquito by the whine of their wingbeat when in flight near one's head. Also distinctive is the overwhelming numbers in which these insects can be found.

Long before humans made an appearance on this earth, most mosquitoes had already established a niche for themselves by sucking blood from animals. There is evidence that these insects may have been feeding on dinosaurs and their relatives during the Cretaceous Period. [168] Although some mosquitoes are still host specific for cold-blooded members of the animal kingdom, most have modified their feeding habits to animals with warmer blood. When humans came along, mosquitoes were there to greet them in great swarms and have pestered them relentlessly ever since.

In addition to the misery caused by biting mosquitoes, diseases transmitted by these pests were killing humans without them even knowing about it. Before and during the periods of recorded history, great civilizations were affected by these pests and their diseases. Mighty armies have been decimated and wars lost because of mosquitoes. [166]

Figure 1-1. Children may suffer more discomfort than adults from the bites of pest mosquitoes. The injected saliva frequently results in an itch-scratch cycle which can lead to secondary infection.

It was not until the mid 1800s that the mosquito was proven to be a disease vector. Patrick Manson, a British medical officer, was first to establish an association between mosquitoes and a human disease (elephantiasis). [199] This revelation shook the medical community and ushered a flurry of research on the public health significance of mosquitoes and their control.

Few insects have been studied more than mosquitoes. Specialists in the fields of entomology, engineering, chemistry, genetics, medicine, wildlife biology, veterinary science and others have interest in various aspects of the mosquito's life. Some mosquito researchers are so specialized that they are known as "culicidologists" (persons who specifically study mosquitoes) and "malariologists" (persons who study various aspects of malaria and its transmission).

Worldwide, there are approximately 3,000 species and subspecies of mosquitoes. Of these, about 170 are found in North America and 51 are found in Idaho. [15]

As a result of tremendous research, great strides have been made in understanding the ways of mosquitoes and their control. Mosquito-borne diseases have been reduced in parts of the world, and these efforts have resulted in increased prosperity and comfort. Nevertheless, 125 years after the dramatic discovery by Dr. Manson, mosquito control is far from being an overwhelming success. Globally, millions of individuals still succumb to mosquito-borne diseases each year and there are untold numbers of domestic livestock and other animals being affected. [217]

Although less dramatic in the great State of Idaho, mosquitoes continue to be a source of complaints. They affect some work and recreational activities, impact our agricultural economy to some degree, and threaten us from time to time with the diseases they carry. At the beginning of the 21st Century, much of the country, including Idaho, had become acutely aware of another threat from the bite of the mosquito, the West Nile virus. This threat has prompted an increased interest in Idaho mosquitoes and their control. Therefore, this guide will help provide a basic understanding about these interesting creatures and some direction for pursuing effective control.

2

Historical Interest in Idaho Mosquitoes

In the very early years of Idaho, even prior to recorded history, enduring mosquitoes was just a part of life. Mosquitoes appeared during the spring thaw and runoff, and they disappeared when the frost came.

Explorers Meriwether Lewis and William Clark were first to write about the mosquitoes of Idaho. On their westward journey through the state (during the fall of 1805), they did not encounter many mosquitoes. However, on their return trip through Idaho the following spring, they found mosquitoes in great abundance. On June 12, 1806, Meriwether Lewis recorded in his journal "the days are now very warm and the Musquetoes our old companions have become very troublesome," and again on June 19, 1806 "Musquetoes have been excessively troublesome to us." [137]

During the 1871 Hayden Expedition through Idaho, George Allen, a botanist, had the following to say about mosquitoes on June 26th at Market Lake (Jefferson County):

> Such an experience as we had last night I shall never forget. I have heard of Mosquitoes before, many of whom would weigh a pound! But I have never seen them before to be counted by the million, crowding the air like the fine dust of an African Simoom. We are encamped upon a level plain - an old marsh with pools of water standing on every side and thus torments are generated beyond all computation. Our camp presented an unusual sight last evening after sundown. Every man was obligated to give himself up to self defense. Some had their mosquito netting around their heads - others their blankets or overcoats. All were in Motion, raving about the camp like so many madmen.... [127]

Figure 2-1. The early settlers may have experienced mosquitoes as abundant as these depicted in this 1975 picture taken in Canyon County.

Many early settlers referenced in their journals the pestiferousness and almost unendurable attacks by Idaho mosquitoes. Quotes from "Covered Wagon Women: Diaries & Letters from the Western Trails" compiled and edited by Kenneth L. Holmes will serve as examples.

Margaret A. Fink recorded in her journal for July 11, 1850, the following:

> The road to-day was very hilly and rough. At night we encamped within one mile of Fort Hall. Mosquitoes were as thick as flakes in a snow-storm. The poor horses whinnied all night, from their bites, and in the morning the blood was streaming down their sides [100]

Sarah Sutton recorded in her journal the following about what happened at their encampment along the Bear River, near Soda Springs, on July 2, 1854:

> as soon as we stoped were attack'd with the most savage warlike enemy and they gave us the alarm by the sound of their horn, and they had prepared themselves, and were well armed with a long sharp spear to meet us for war, and as soon as we met there was heavey battles fought, but on our side there was some blood shed it is true, but no lives taken, but on the enemys side hundreds kill'd and wounded but none missed. they were of the Musqueto tribe... [101]

On July 24, 1883, Mary Matilda Surfus recorded in her journal the following about the mosquitoes along the Snake River near Bruneau:

> July 24th camped by bruno creek stoped to get dinner on a Biou and the mosketoes really drove us out the horses ran up on the hill and refused to eat the children screamed and twas out of the question to keep the mosketos off of us so the men hitched up and drive up the hill. [102]

Prior to 1830, virtually all mosquito breeding in Idaho was a result of natural and seasonal occurrences associated directly or indirectly with rain, snow and resulting runoff and percolation. However, during the next three decades, a new breeding source would be introduced to Idaho mosquitoes, irrigation. When Reverend Henry Spaulding of the Lapwai Mission on the Clearwater River and the Mormon settlers at Fort Lemhi (and afterwards Cache and Malad Valleys of southeastern Idaho) diverted stream water onto the land, more than a half dozen biologically flexible mosquito species found the man-made habitats most favorable. The 1862 Homestead Act, 1877 Desert Land Act, 1894 Carey Act and 1902 Reclamation Act contributed a great deal to the settlement of Idaho and the development of the all-important irrigation systems for agriculture. In addition to making the desert "blossom like a rose," the irrigation process generated an increase in the production of mosquitoes. [211]

Without a doubt, H. G. Dyar, a preeminent authority on mosquitoes, contributed significant information pertaining to the species occurring in Idaho. From 1901 to 1929, he authored several hundred papers on mosquitoes and wrote *The Mosquitoes of the United States* in 1922. He visited Idaho several times and conducted extensive collecting in the northern part of the state. [57] He described 13 mosquito species known to exist in Idaho.

During the latter part of the 19th Century and into the mid-20th Century, Idahoans became aware that mosquitoes were more than just a pest, they were also vectors of disease. In 1897, Ronald Ross proved that malaria was caused by mosquitoes. This news was relevant to Idaho because malaria was known among the settlers. [76] With Ross' discovery, as well as the discovery of the mosquito as a vector of yellow fever by Walter Reed in 1900, agencies of federal, state and local governments began to show an interest in mosquito protection and control.

A number of mosquito abatement programs were recorded for the neighboring states of Washington, Oregon and Utah during the 1920s and 1930s, but the extent of active mosquito control in Idaho is not known. [46, 76] However, construction projects to promote drainage during the early 1930s under the Civil Works Administration and the Civilian Conservation Corps contributed to some mosquito control. [200, 204]

By this time, many of the geographical features in Idaho had received names. The significance of mosquitoes has resulted in a number of features being named after them: eight creeks, a bay, reservoir, lake, ridge, spring and two peaks. [213]

During the years of World War II (1941-1945), the federal government had an interest in Idaho mosquitoes because of the military operations in the state, notably Gowen Field in Boise and Farragut Naval Training Center on Lake Pend Oreille. The U.S. Public Health Service Malaria Control in War Areas (MCWA) conducted a number of mosquito surveys in the state during this time. [78, 84, 120] Thirty-

two species of mosquitoes were known to exist in the state at this time. [84]

During the Korean War years (1950-1953), several mosquito surveys were conducted in the state by the Idaho Department of Health and the U.S. Public Health Service. As a result, five additional species were reported as new state records from northern Idaho. [214] During the same period, a significant work which included Idaho mosquitoes was the U.S. Department of Agriculture Handbook, entitled *Mosquitoes of the Northwestern States*. [201] This publication identified the distribution of known Idaho mosquitoes by county.

As a result of public and political concerns regarding the mosquito problems in Idaho and the potential for mosquito-borne diseases, a part-time public health biologist was jointly hired by the Idaho Department of Health and the Boise City-Ada County Health Department in 1955. The primary responsibilities of this individual were to develop enabling legislation authorizing the formation of mosquito abatement districts, conduct mosquito surveys and investigate mosquito problems. Training was provided by the Public Health Service, Centers for Disease Control (CDC).

In 1959, Idaho's Mosquito Abatement Act was passed by the Legislature and over the years, about a dozen abatement districts have been formed (see Chapter 7). In addition, some cities implemented their own spray programs. In Boise, the City-County Health Department (Central District Health Department) provided mosquito control from 1967 to 1993. [208]

In conjunction with the training of the Public Health Biologist, the State and the U.S. Public Health Service conducted additional mosquito surveys throughout the state during the remainder of the 1950s and 1960s. These surveys were most often associated with calls for assistance by city and county leaders and private citizens. During this time, Idaho mosquito identifications were made by staff members of the Public Health Service and the University of Utah, which resulted in a number of published works. [84, 145, 155, 151] In 1971, the author of this work published a checklist of the mosquitoes of Idaho, listing 47 species and subspecies. [14]

In 1971, the Idaho Legislature created seven autonomous health districts in the state, comprising of four to eight counties each. As a result of the demand for consultation and training on vector control matters (which included mosquito control), a specific vector control position was added to the Idaho Department of Health and Welfare in 1973.

The 1952 U.S. Department of Agriculture handbook on mosquitoes [200] was revised and updated in 1972. [76] General support for mosquito control was provided by the Department of Health and Welfare to the health districts and mosquito abatement districts through the 1970s and 1980s.

A significant work pertaining to Idaho mosquitoes was a 1981 systematics manual on the identification and geographical distribution of the mosquitoes of North America (north of Mexico). [50] The manual reported 49 mosquito species and subspecies as existing in Idaho. Based on this work, a provisional county-by-county distribution list for the mosquitoes of the state was produced. [94]

In the latter 1980s, the State's vector control program, within the Division of Environment, Idaho Department of Health and Welfare, fell on hard times. As a result, the program was eliminated in 1992, bringing to an end more than four decades of vector control activities at the state level. This act essentially left the local health agencies and mosquito abatement districts on their own in dealing with vector matters. In 1995, the Idaho Department of Agriculture assumed some of the mosquito control oversight of the defunct program.

Nomenclatural changes in 2000 resulted in most of the *Aedes* mosquito species being placed in the resurrected genus *Ochlerotatus* (pronounced O-clair-ro-tah-tus), much to the chagrin of individuals who were accustomed to the more familiar name. [179]

In the last several years, as a result of the westward advance of the West Nile virus, federal, state and local governmental agencies have renewed their interest in Idaho mosquitoes, their potential for disease transmission, and control. [108]

The latest note of interest is the discovery of two unreported mosquito species in the state in 2002 by the author (*Ochlerotatus decticus* and *eudes*) and the establishment of a current list of Idaho mosquitoes. [15] To date, the number of mosquito species and subspecies known to exist in the state is 51: 3 *Anopheles*, 2 *Aedes*, 32 *Ochlerotatus*, 7 *Culex*, 6 *Culiseta* and a single species of *Coquillettidia*. [15]

3

Life History of Mosquitoes

When a mosquito bites, there is usually only one thought on our mind – to swat it. If we are lucky, we get the mosquito and often with a splat of our own blood. Frequently we miss. But, because of our knowledge of the persistence of this insect, we sometimes watch for a repeat attack so we can have another chance to swat at it.

For the most part, we as humans give little thought as to why the mosquito wants to bite so bad that it comes after us time and again to try and suck our blood. But the answer is quite simple - maternal instinct. Biting mosquitoes are mated females seeking protein to develop their eggs so they can perpetuate the species. Their abundance and persistence in wanting to feed can be unnerving. This chapter provides information on the mosquito's characteristics and life history, as it applies to Idaho species.

Figure 3-1. The bite of the female mosquito is often a painful reminder of one of the characteristics of this insect.

Mosquito Characteristics

Mosquitoes are a group of small, primitive, delicate, winged flies in the insect order Diptera and of the family Culicidae. The adults are readily identified by their long legs, slender body, an elongated proboscis, and the presence of scales on the body, legs, and wing veins and margin (the scales are similar to those of butterflies and moths). This group of insects undergoes complete metamorphosis, passing through four distinct stages in which the structures and functions are completely different. These stages consist of egg, larva, pupa and adult, the non-adult stages requiring water for development. Little mosquitoes are not "baby mosquitoes," but represent small adults or different species.

Adults

Although most authors start the life history of a mosquito with the egg, this work starts with the adult, since this is the stage in which individuals are most familiar and may have an interest in knowing more about them. The discussion starts right after mosquitoes emerge as adults.

Mating

Depending on the species and the season, mating may have occurred during the previous fall or anytime during the current year. Mating usually occurs in the vicinity of the breeding area, within a few days after emergence. For most mosquitoes, mating is initiated with the male and female in flight. Mating may occur in flight, on vegetation, or on the ground (mating only takes a few seconds). [55] Males of most species are known to form great compact aerial swarms near visual features of the landscape such as trees, bushes, rocks, fence posts and even animals and humans. These swarms are often called "mating swarms" and females entering the swarm will be mated. However, mating activities may also occur without fanfare in the vicinity of the breeding area. In addition, males of several Idaho species are attracted to females flying around their vertebrate hosts. [54, 143, 185] Pheromones and the sound of the mosquito's flight are also involved in the mating process. [78, 185] After mating (which can be multiple times for the males), the role of the male mosquito has been completed and is short-lived thereafter. The female, on the other hand, is just beginning her primary purpose of life, producing and laying eggs. [44]

Feeding

Both male and female mosquitoes of most species require the nectar of flowers and other plant fluids as a source of food at one time or another during their lives. [99, 147] The males require this during their entire lives and do not bite. The females of most species require a blood meal as a source of protein to mature her eggs; and many species have specific preferences as to their hosts. Some species may prefer the blood of amphibians and reptiles, others prefer birds, and others prefer mammals and humans. Some species may not be so particular and will feed on animals of two or more groups as the opportunity presents itself. In addition, some species may display seasonal shifts, preferring one animal group in the spring and summer, and feeding on another in the fall. [3, 206]

Contrary to the above information, females of some species can develop a few viable eggs without the benefit of a blood meal. This phenomenon is called autogeny and for most species, applies only to the first brood. Thereafter, blood meals will be required before laying more eggs. [39, 43] Autogeny may also contribute to host preference shifts of certain species. [198]

The time of day in which the female mosquito feeds can be generic and species specific. Light intensity, temperature, relative humidity and several other factors influence activity periods, although the reason is not completely understood. [187] Generally, there are three periods of activity, namely diurnal (within hours of daylight), crepuscular (during hours of twilight – the periods between sunset and darkness in the evening and darkness and sunrise in the morning) and nocturnal (during hours of darkness). However, some species are active during several periods. In addition, a change in light intensity during the above-mentioned periods may also have an effect on female activity. Thus, females of some species with mostly crepuscular activity may start feeding earlier on a cloudy day. [146] Some forest feeding diurnal species prefer less light, so by simply stepping into the direct sunshine, a person can avoid being bitten. [83] Moonlight also has an effect on mosquito activity. [9] Information about the feeding habits of individual species is provided in Chapter 5.

The distance in which female mosquitoes will fly from the breeding site to find suitable hosts varies depending on host availability and climatological conditions. Some females travel no farther than a few hundred yards. Females of many species will travel a mile or so from the breeding site. Females of three common Idaho species are strong fliers and are known to travel 5 to 20 miles: *Aedes vexans* (Inland Floodwater Mosquito), *Ochlerotatus nigromaculis* (Irrigated Pasture Mosquito) and *Culex tarsalis* (Western Encephalitis Mosquito). [5, 42]

The female mosquito is attracted to its host by a combination of sensory cues. Odor flumes, visual cues, heat stimuli, and several chemosensory cues (CO_2, lactic acid, octenol, etc.) are considered most important. [45]

Figure 3-2. This female *Aedes vexans* (Inland Flood-water Mosquito) has just started to feed. Compare the size of her abdomen with the engorged female in Figure 3-3.

Not only do such cues assist females in long-range orientation, they also assist in short-range approach to the host. Depending on the species, the female may be cautious in approaching the host, or go for the direct and immediate approach – "right to the jugular vein," so to speak. She may "taste" (probe) the host several times to find the right place to feed, but when she is ready, the feeding process begins in earnest.

The piercing and pumping parts of the proboscis are unique. Although it appears to be a single structure, the proboscis is actually made up of seven long, slender mouthparts. The scaled outer sheath (labium), that part which is readily observable, partially encloses the actual piercing parts (fascicle). During the penetration process, the labium kinks posteriorly as the piercing and sucking parts are forced into the skin. The structure of the male's proboscis is unlike the female's and it cannot bite. The bites of some female mosquitoes are benign, but others are quite painful, the latter ones requiring the greatest and most forceful slapping action. Prior to withdrawing blood, the female injects saliva to prevent the blood from coagulating. The itching and welting at the site of the bite is a reaction to this fluid. [164]

Interrupted feeding, primarily due to movement or defensive behavior of the host, will most often result in multiple feedings from the same host or other hosts. The "unfull" female continues to respond to the feeding impulse until she has consumed a full blood meal. [220] Multiple meals from different hosts during the life of the female mosquito presents an important public health factor mentioned in Chapter 4.

The amount of blood which the female mosquito can consume and fly away with is amazing. One study of natural feeding habits of *Ochlerotatus nigromaculis* (Irrigated Pasture Mosquito) on a dairy farm demonstrated that a 3.1 microgram mosquito could consume 7.2 micrograms of blood – more than twice its body weight. [132] The feeding process takes less than a couple of minutes. After feeding, the female flies to a vertical surface and reduces the bulk of the blood meal by passing most of the liquid. The remaining protein-rich component is utilized to mature her eggs.

Figure 3-3. This female *Ochlerotatus increpitus* may consume twice its weight in blood in one feeding.

Breeding Sites

Most female mosquitoes generally have precise ecological preferences for breeding sites to lay their eggs. Some, however, are less particular and utilize a variety of habitats. Here again, the female utilizes a number of cues (probably involving visual, tactical and chemical) to select the right location. [104] They do not necessarily return to the place where they emerged as adults; and any site that will meet their requirements for egg laying is satisfactory. In Idaho, such breeding places can be classified in the following ecological groups and subgroups: [49, 83, 211]

Temporary Water Sources

- Floodwater associated with river and stream overflows in valleys
- Snowpools from snowmelt that collects in a multitude of pools in undrained depressions in meadows and woodlands
- Rain pools

Recurrent and Semi-permanent Water Sources*

- On-field irrigation sources such as fields, forage crops and pastures
- Off-field irrigation sources such as seeps from irrigation canals, laterals, ditches; roadside ditches; borrow pits; depressions on nonarable land and other undrained areas that can accumulate irrigation water
- Retention ponds, street catchbasins, gutters and culverts

Permanent Water Sources*

- Margins of slow-flowing rivers, streams and streambed pools
- Margins of lakes, reservoirs and ponds
- Springs, swamps and marshes
- Wastewater lagoons
- Log ponds
- Gravel pits

Treeholes

- Rot holes, stumps

Artificial Containers

- Rain gutters, undrained swimming and wading pools, boats and wheelbarrows containing water, barrels and old oil drums, used paint cans and miscellaneous utility containers, food and beverage containers, flower vases and urns, birdbaths, ornamental fountains and pools, stock tanks and pet waterers, open cisterns, saucers under potted plants containing water, unused tires, improperly constructed septic tanks, standing water in crawl space under home, and a multitude of impervious trash that can hold water.

* Depending on the circumstances, some of these water sources could be permanent or semi-permanent.

Examples of mosquito breeding sites in Idaho are provided in Figures 3-8 through 3-21.

Other influencing factors that contribute to making the above-mentioned breeding sites acceptable to the female may include the amount of organic matter (pollution, decomposing vegetation, etc.) in the water, alkalinity, amount of sunlight exposure, and types and density of emergent vegetation in the water. The amount of water that may be attractive to the female for egg laying purposes may be very small. An animal hoof print or a partially filled discarded beverage container may be perfectly acceptable. Mosquito breeding does not take place in active or deep open water.

Eggs

Once the eggs are fully developed, they are retained in the ovaries of the female until she can find a suitable breeding site. [110] Upon finding the right place, the female prepares to lay her eggs. The egg-laying process (oviposition) and egg structure is specific to the groups (genera) of mosquitoes, with a few exceptions. [103] Females of *Culex*, *Culiseta* and *Coquillettidia* mosquitoes lay non-desiccation resistant eggs in raft-like masses on the water surface. The exception is females of *Culiseta morsitans* which lay their eggs in raft-like masses on damp soil above the water level. Most *Aedes* and *Ochlerotatus* females lay their desiccation resistant eggs singly (not in rafts) on damp soil above the water level of the breeding site. Females of the treehole species of *Ochlerotatus* lay their eggs singly in treeholes on the damp vertical wood surfaces above the water level. *Anopheles* females lay non-desiccation resistant eggs singly, directly on the water surface.

During oviposition, the eggs pass through the oviduct and are fertilized by the male sperm which has been stored in special organs (spermathecae) in the female's body since mating. [73] Females retain sperm from the male for life and can use it for multiple batches of eggs. [199]

Figure 3-4. Egg raft and first instar larvae of *Culex tarsalis* (Western Encephalitis Mosquito). Note caps on the ends of eggs where larvae emerged.

The eggs are soft and white when laid and they turn brown or black and harden within 1 to 2 hours. The number of eggs deposited varies, but there are typically 50 to 200 per batch. [76] It has been reported that a single female of the species *Culiseta inornata* laid 1,100 eggs during her life and more from other species have been reported. [125] The eggs are very small, elongated ovals and are usually more pointed at one end, with a length of about 1/32 inch (0.8 mm). Depending on the genus and species, many eggs are sculptured in various patterns and some are constructed with a pair of lateral "floats." Good information about the characteristics of western United States *Aedes* and *Ochlerotatus* eggs has been published. [140] Although individual eggs are difficult to see without magnification, egg rafts are clearly visible on the water surface with the unaided eye.

The duration of the egg stage (once laid) varies greatly. Hatching maturity after being deposited can be 120 hours at 80° F for one species and less than 15 minutes after being inundated with water for another. [4] Eggs of most of the *Aedes* and *Ochlerotatus* species will not hatch until they have been subjected to cold prior to being flooded the next year; these are considered single-brooded species (univoltine). Other species of the same genera hatch upon flooding the same year and multiple broods can be produced during the year (multivoltine). Eggs of some of these species are known to remain viable for several years without being flooded with water – three years or more for *Aedes vexans* (Inland Floodwater Mosquito) and *Ochlerotatus sticticus* (Floodwater Mosquito). [75, 161] Although somewhat varied by species, once eggs are flooded or they are laid directly on the water surface, they hatch within minutes to several days if water conditions are suitable. [112] A decreased oxygen concentration in the water provides a strong hatching stimulus. [77] Eggs of a number of species may not hatch with the first flooding. Hatching delays increase the survival of the species. [66]

Larvae

At the appropriate time, each mosquito larva frees itself from the egg with the assistance of an "egg burster" located on the top of the head. [17, 113] The egg burster creates a rupture in the egg shell allowing the larva to escape. At hatching, the mosquito larva is very small - about 3/64 inch (1 mm) in length. The hatchling is called the "first instar." Within a short period of time, it will molt by shedding its tight larval skin and become the second instar. As it feeds and grows, it will molt three more times. The fourth instar is the last larval stage and when mature it will measure 1/4 - 13/32 inch (6 - 10 mm) long, depending on the species.

Figure 3-5. Fourth instar larva of *Culex tarsalis* (Western Encephalitis Mosquito). This is the active feeding stage of the immature mosquito.

The larva (commonly called "wiggler") has three distinct body regions, head, thorax and abdomen, all of which are adorned with numerous and conspicuous setae (hairs, hair tufts, bristles). The head is sclerotized and highly movable. It has distinct antennae, simple eyes and prominent mouthbrushes. The thorax is large and indistinctly segmented, whereas the elongated abdomen has ten segments, although only nine are evident. [50] Most unique of the abdominal segments are segments VIII and X. Segment VIII contains the external respiratory system, which is unique among the three generic groups of Idaho mosquitoes. Species of *Culex*, *Culiseta*, *Aedes* and *Ochlerotatus* possess a sclerotized siphon, or breathing tube. Larvae of these mosquitoes hang downward from the water surface by their siphons when respiring. Species of the genus *Anopheles* lack a siphon; the respiratory

spiracles are directly on the dorsal surface of segment VIII (Figure 9-64). These larvae lie horizontally at the water surface. The siphon of *Coquillettidia perturbans* (Cattail Mosquito) is short and modified to form a strongly sclerotized, pointed and saw-like process (Figure 9-66). This species obtains oxygen by inserting the modified siphon into the tissue of submerged plants. It does not need to go to the surface to respire. Segment X (commonly called the anal segment) is offset and bears a sclerotized saddle, two pairs of gills and the excretory opening. As the larvae mature, variations to the size, shape and number of some of their characteristics takes place. [196] Most of the larval characteristics mentioned are important for identification purposes.

The primary function of the larval stage is to obtain sufficient nourishment for its biological functions as well as for those of the pupa and newly emerged adult. With the exception of *Coquillettidia perturbans* (which attaches itself to submerged plants) the larvae are very active, moving around in their aquatic environment while feeding. Although each species has its particular niche, it is not uncommon to have several species occupying the same breeding area at various stages of development. As many as five species have been reported together in one Idaho habitat. [15] Feeding is accomplished by the sweeping action of the mouth brushes or by actual nibbling. Food consists mainly of small plant and animal organisms and particles of organic matter. The larvae of *Anopheles* feed at the water surface by rotating their heads 180° to sweep the surface film.

The sweeping action of the mouth brushes propels the larvae slowly through the water at the surface and during subsurface feeding. Faster movement is accomplished by the rapid flexing motion of the distal portion of the abdomen from side to side. This movement is particularly noticeable when the larvae seem to "dive" in unison when disturbed (an alarm response). The larvae are sensitive to vibrations and their eyes detect movement and changes in light intensity. [184]

The duration of the larval stage varies depending on the species and water temperature. Most species will complete this stage in 7 to 14 days. Larvae of mosquito species associated with irrigation and other recurrent water sources can complete the stage in 4 or 5 days. [109] Larvae of several species that hatch in the late fall may overwinter in this stage. [39, 122]

Pupae

Pupation commences when the fourth larval instar molts (fourth molt). As the larval skin is shed, the pupa (commonly called "tumbler") emerges. When the cuticle hardens, the pupa resembles a dark oversized comma. Although this is a non-feeding stage, pupae are very active when disturbed, tumbling below the water surface only to float back to the surface because of their buoyancy. As with larvae, the pupae must respire and this is accomplished with a pair of short flared processes (called "respiratory trumpets") on the dorsal surface of the cephalothorax. The pupa of *Coquillettidia perturbans* obtains oxygen by inserting its trumpets into the tissue of submerged plants.

The pupal state is generally short (about 3 to 4 days), less for some species associated with irrigation and longer for others. [17] In this stage, however, a most important transformation takes place. The larval form, which was so adapted to aquatic life, completes a transformation to the adult form, which is adapted to a terrestrial existence.

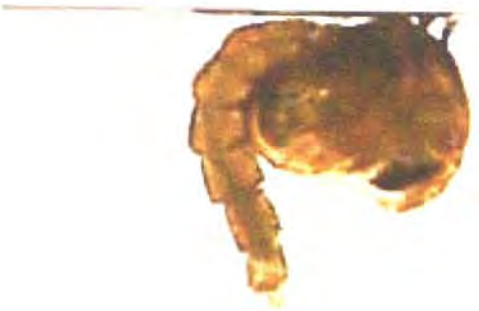


Figure 3-6. Pupa of *Culex tarsalis* (Western Encephalitis Mosquito). Although very active in the water, this is a non-feeding stage in which the insect goes through a transformation process to the adult form.

Emergence

The emergence of an adult mosquito is a dramatic event. It is also a vulnerable time since during the emergence process, the mosquito can neither submerge nor fly. The first indication of the pending emergence is the straightening of its tail until it is parallel to the water's surface. The adult creates pressure within the pupal skin and it splits on the dorsal surface of the cephalothorax. Using the cast skin as a flotation device, movement of the various body parts allows the adult to emerge in two minutes or so. After the adult's body dries and hardens sufficiently, it flies away. Thus, the mosquito that we know so well is developed.

Figure 3-7. A male *Culex pipiens* (Northern House Mosquito) emerging from its pupal skin at the water's surface. At this moment, the mosquito is very vulnerable because the body is too soft to allow it to fly.

Longevity and Overwintering

The life of an adult mosquito is generally short during the warmer months; most do not survive more than a few weeks to about 30 days. [76, 201] However, some have been known to live three months when weather conditions are suitable. [201] Males die earlier than females. In addition, adult female mosquitos that overwinter are naturally older than those that do not. The importance of longevity for vector effectiveness will be mentioned in Chapter 4.

As winter approaches, females of the *Aedes* and *Ochlerotatus* species have already laid their eggs and died. The eggs of these species will remain dormant until the next spring. Fertilized females of *Culex*, *Culiseta* and *Anopheles* generally overwinter as adults. The females seek shelter in naturally protected areas such as animal burrows, cavities created by rotted tree roots, caves, deep crevices in rock formations, rock piles, etc., and man-made shelters such as old mines, food-storage cellars, crawl spaces under structures, basements, in dwellings, etc. [38, 192] Possible exceptions are *Culex erythrothorax* (Tule Mosquito) and *Culiseta morsitans* which have been reported to pass the winter as larvae. [40, 122] *Coquillettidia perturbans* are known to overwinter in the larval stage. [17]

Figure 3-8. A rot hole, about eight feet up this cottonwood tree in Gem County, contained water and produced numerous larvae of *Ochlerotatus sierrensis* (Western Treehole Mosquito).

Figure 3-8. This flooded gutter in Boise contained thousands of larvae and pupae of *Culex pipiens* (Northern House Mosquito).

Figure 3-9. Larvae of *Anopheles freeborni* (Western Malaria Mosquito) and *Culex territans* were collected in this side-channel of the Boise River in Ada County.

Figure 3-10. This marsh area along the Snake River in Elmore County produced great numbers of *Ochlerotatus dorsalis* (Salt Marsh Mosquito).

Figure 3-11. This cemetery monument with water-filled flower wells, as well as others were breeding many *Culex pipiens* (Northern House Mosquito).

Figure 3-12. As depicted in the insert picture, several tires in this pile located in Boise contained water and thriving populations of *Culex pipiens* (Northern House Mosquito).

Figure 3-13. Standing tail water in this field in Canyon County was producing larvae of *Ochlerotatus dorsalis* (Salt Marsh Mosquito) and *Oc. nigromaculis* (Irrigated Pasture Mosquito).

Figure 3-14. Water-filled depressions in the sedge bordering this mountain stream in Valley County were breeding five species of snowpool mosquitoes, namely *Ochlerotatus decticus, Oc. eudes, Oc. execrucians, Oc. fitchii* and *Aedes cinereus* (Little Smokey Mosquito).

Figure 3-15. Numerous larvae of *Culex tarsalis* (Western Encephalitis Mosquito) and *Culex pipiens* (Northern House Mosquito) were breeding in this standing water in a community park in Canyon County.

Figure 3-16. Hundreds of mosquito larvae and pupae from one dipper-full of water (insert) from this subdivision retention pond in Canyon County suggests that this is a major breeding source of mosquitoes (Courtesy of Jami Delmore, Southwest District Health Department).

Figure 3-17. Waste irrigation water at this site in Gem County was producing a considerable number of larvae of *Anopheles freeborni* (Western Malaria Mosquito).

Figure 3-18. This depression containing snowmelt water along a creek in Boise County contained many larvae of *Ochlerotatus increpitus* as early as the last week of March.

Figure 3-19. *Ochlerotatus nigromaculis* (Irrigated Pasture Mosquito) and *Aedes vexans* (Inland Floodwater Mosquito) were breeding in this standing irrigation water in a Canyon County pasture.

Figure 3-20. This roadside retention ditch in Ada County contained many larvae of *Culex tarsalis* (Western Encephalitis Mosquito) and *Culex pipiens* (Northern House Mosquito).

Figure 3-21. This trapped runoff water in Elmore County had been standing long enough to produce many larvae of *Culiseta inornata* (Winter Marsh Mosquito).

4

Public Health and Economic Importance

On a worldwide basis, the effects of diseases transmitted by mosquitoes is enormous. Millions of humans, and an untold number of wildlife and domestic animals, are affected each year by viruses or parasites delivered by infected mosquitoes. [217] The statistics are staggering and beyond imagination for most of us. The diseases and associated deaths, untold suffering and economic impact seem so distant, in both miles and time. Contributing to this distance is the fact that none of the mosquito-borne diseases known to occur in the United States have had a significant impact on the citizens of Idaho for greater than 40 years. Most concerns about mosquitoes in Idaho have been their capacity to be "vectors of misery and discomfort" (pests). [159] The recent arrival of West Nile virus in the United States and its spread westward has changed that reality; the public health significance of mosquitoes has grabbed our attention. This chapter provides information about a few mosquito-borne diseases that have historically occurred or still occur in Idaho, in addition to the West Nile virus, and the problem of pest mosquitoes.

Malaria

Malaria was a common disease during the settlement of the Idaho territory. When Idaho became a state in 1890, it was still not known what caused malaria. Many people suffered and some died of the disease. [76, 79] With the findings of Ronald Ross in 1897, the cause of the disease became known to the world.

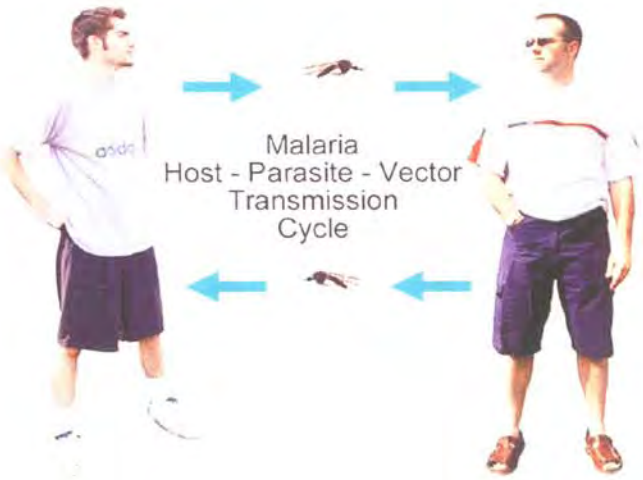


Figure 4-1. Malaria parasites are transmitted from person to person by the bite of *Anopheles* mosquitoes.

Malaria is caused by tiny protozoan parasites (one-celled organisms, many times smaller than a blood cell) which are transmitted from person to person by the bite of infected *Anopheles* mosquitoes. There are four types of malarial diseases

(humans being the reservoir, or host) and the symptoms vary by type. Technical aspects of the disease are described in detail by a number of authors. [11, 141, 186] The most notable symptoms include recurring bouts of chills, fever, and sweats, each bout lasting a few hours. The symptoms represent the various stages in which the parasite is developing in the body. The disease may be mild in some forms, or progress to more severe complications, even death, in the more serious forms.

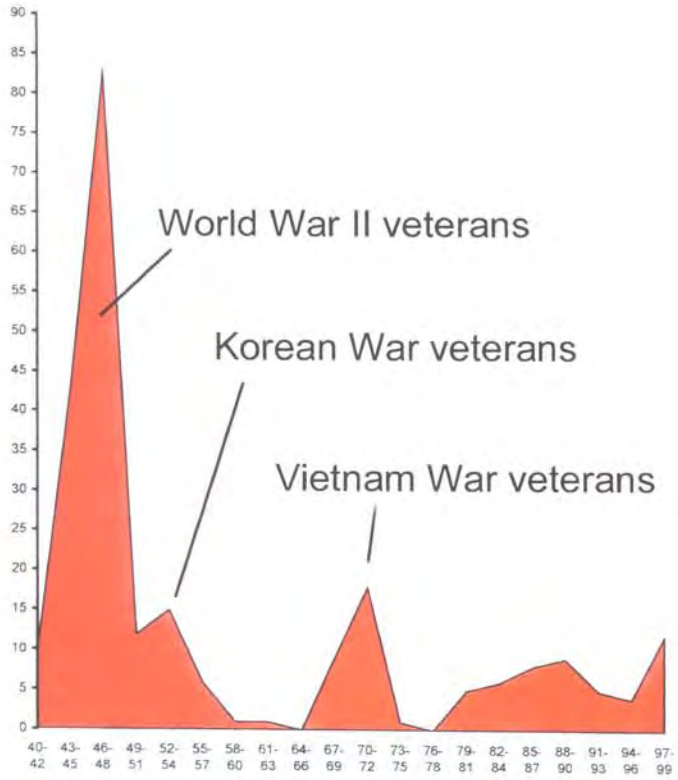


Figure 4-2. Idaho malaria cases from 1940 to 1999. Source: Records of Idaho Department of Health and Welfare.

Should an *Anopheles* mosquito feed on a human with malaria, the parasite goes through a sexual cycle and develops within the mosquito's body. This cycle requires seven or more days under favorable environmental conditions. Weather may be the most important limiting factor of the disease in Idaho, determining whether or not the mosquito will live long enough for completion of the parasite's sexual cycle. The second generation of the parasite becomes concentrated in the mosquito's salivary glands. This stage is transferred to other humans during the next blood meal. This is the only natural manner in which malaria is transferred from person to person. Although rare, malaria can also be transmitted by exposure to infected blood products, contaminated needles or syringes, and from mother to child in the womb. [34]

At the beginning of the 20th Century, malaria had subsided so there were comparatively fewer cases in Idaho. [79] Therefore, when a probable outbreak occurred in Horseshoe Bend in the latter 1930s (probably 1937 based on *Anopheles* mosquito collection records at that location), it was of interest to state and federal health agencies. [120] Although the details of the outbreak are few, *Anopheles* control efforts in the area were implemented. The Horseshoe Bend area and elsewhere in the Payette and Boise River valleys were considered to have "larger than average numbers" of *Anopheles freeborni* (Western Malaria Mosquito). [79] Malaria case reporting in Idaho during this time was on a voluntary basis, and reports did not indicate whether patients contracted the disease within the state or elsewhere. [79]

During the years of World War II (1941-1945) and beyond, the U. S. Public Health Service made a number of visits to Idaho as part of the Malaria Control in War Areas (MCWA). Of concern in Idaho and elsewhere were returning military personnel carrying the malaria parasite who could contribute to an increase in the disease in areas where *Anopheles* mosquitoes were numerous and environmental conditions were suitable. [67, 79] Figure 4.2 demonstrates peaks of reported malaria cases which coincides with returning war veterans.

The reemergence of malaria as a public health problem in the United States may become a reality due to increased global travel, increased immigration of people from malaria-endemic areas, growing antimalarial drug resistance, changes in the weather and the presence of competent mosquito vectors. [82, 221] In fact, within the past 15 years, the number of cases in the United States has been increasing. [23] Nationwide, ten outbreaks of probable "locally acquired" (autochthonous) mosquito-borne malaria have been reported since 1992. [29] Considering this, parts of Idaho may also be at risk, particularly if global warming trends should continue.

Western Equine Encephalitis

Western equine encephalitis (WEE) in humans and horses is an important arthropod-borne viral

(arboviral) illness in the western United States. Historically, it has been the most important mosquito-borne viral disease in Idaho. [7, 12, 200] Symptoms range from mild flu-like illness to high fever, meningeal signs (aches in the head and neck), stupor, disorientation, and coma. [8] The mortality rate is 2 to 15 percent. Children one year old or younger are at the greatest risk for permanent brain damage. [88] In horses and other equines, the mortality rate is 10 to 40 percent. [88]

The cause of WEE was not known until 1930, when the virus was isolated from horses during an unprecedented outbreak in the San Joaquin Valley of California. [128] During the 1930s and 1940s, several other very extensive outbreaks occurred in the west, affecting hundreds of thousands of horses and other equines. [180] In 1933, a WEE outbreak was centered along the Wasatch Front of Utah and extended north into Idaho, affecting many horses in both states. [12] In 1935 alone, as many as 2,400 horse cases of WEE were reported in Idaho. [200] A vaccine for horses was developed in the late 1930s and made available to veterinarians. Human cases of the disease were not linked to WEE until 1938, when the virus was isolated from the brain of a child in California. [180]

The extent of human cases of WEE in Idaho during the early years of the disease is not known because physicians were only voluntarily identifying the disease from other forms of encephalitis. However, certain physician reports as early as 1950 specifically identified WEE as the cause of disease.

Although mosquitoes were considered to be possible vectors of the disease, it was not until1941 that the vector was discovered. During the investigation of WEE in the Yakima Valley of Washington, all isolates of the virus were from *Culex tarsalis* (Western Encephalitis Mosquito). [89] Subsequently, further investigations have incriminated other mosquitoes as vectors of the disease as well, but *Culex tarsalis* remains the primary and most important vector of the disease. [76] Outbreak investigations have revealed that WEE occurrences were associated with increased cumulative precipitation early in the year, above average monthly temperatures during the spring, and high vector populations. [95, 160]

The disease cycle of WEE in the environment and how it gets from the mosquito to equines and humans is of interest because the overwintering reservoir of the disease is not fully known. It has been demonstrated that snakes and possibly other cold-blooded animals may harbor the virus. [72, 207] It has been hypothesized that when females of *Culex tarsalis* come out of winter diapause, the first animals available for them to feed on are the "cold-bloods," possibly acquiring the virus. As birds (their preferred host in the spring) become more available, the mosquito starts feeding on them (particularly the young) and possibly passing on the virus. [176] Birds become infected, *Culex tarsalis* feed on them, and amplification of the virus occurs in the local ecosystem [176] As a result, the disease becomes enzootic or established in the bird population. Contributing to the outbreak potential is the fact that *Culex tarsalis* is a multi-brooded species and requires a blood meal to mature the eggs of each brood; the longer the female lives, the greater chance of her becoming a vector and passing on the virus. Thus, a long-lived (old) female is most dangerous as a potential vector of the disease. [160] Consequently, public health workers utilize birds (often chickens) as sentinels to detect viral activity. This can help to determine impending risk. [177] (See Chapter 8 for more information on surveillance.)

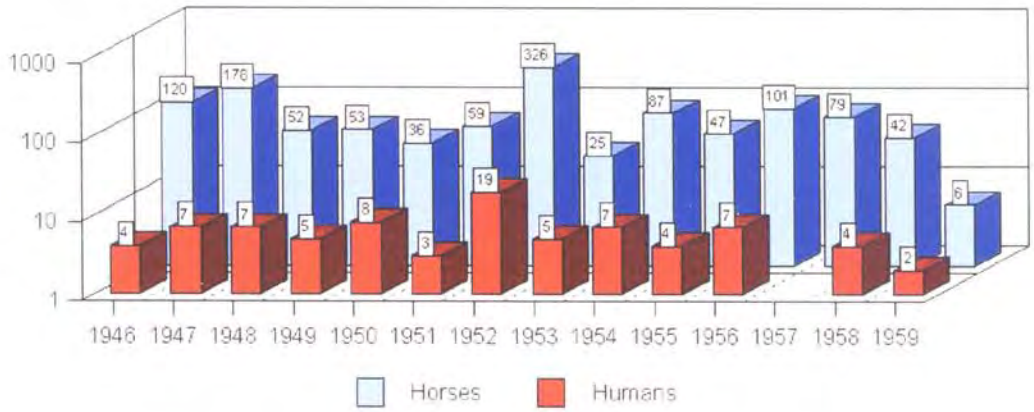


Figure 4-3. Idaho encephalitis cases in humans and horses from 1946 to 1959. Source: Records of Idaho Department of Health and Welfare and Department of Agriculture.

Of significance is the midsummer shift in host-feeding by *Culex tarsalis* from birds to larger animals. [176] This makes the mosquito a "bridge vector," transmitting the disease from birds to larger animals and humans. When this occurs, equines and humans become more at risk and if infected become dead-end hosts. Dead-end hosts may become infected but they typically do not produce enough virus in their blood to pass it on to the next feeding mosquito. [96] Often, the increased numbers of equine cases of WEE in a given area may also predict the immediate potential risk for human cases in the same area. [16] An after-the-fact review of equine and human cases may show corresponding increased numbers for the disease.

Over the years, the Idaho Department of Agriculture has informed health authorities when there is an increase of equine cases. [53, 65] As appropriate, health authorities have notified local health agencies, and press releases have been issued to alert the public. Equine cases are becoming less common due to the use of effective vaccine.

From 1964 to 2000, no human cases of WEE were reported in Idaho, despite occasional increases in equine cases. [106] Since 1970, most western states have shown a significant reduction in human cases of the disease (with the exception of 1975). There may be a logical but unconventional reason for this. During known epizootic outbreaks of WEE and St. Louis encephalitis in the Central Valley of California from 1958 forward, there were very few human cases. A study was initiated to determine the probable cause. The most compelling reason was the habit changes of the human population during the primary feeding time for *Culex tarsalis*, which starts about one-half hour after sunset. The conclusion that had the greatest epidemiological fit was "air conditioning" and "television." [70, 178]

St. Louis Encephalitis

Although St. Louis encephalitis (SLE) has been the most important mosquito-borne arbovirus in the United States prior to 2000, it has not had the same impact on Idaho as WEE. This may be due to fewer clinical human cases, and that the disease is not apparent in horses and other equines. Symptoms in humans are similar to WEE. [8] The mortality rate has been reported from 3 to 30 percent with the elderly being at the greatest risk. [10]

The SLE virus was isolated in 1933 during an outbreak in St. Louis, from which it received its name. [121] Although mosquitoes were suspected as the vector, SLE was not isolated from mosquitoes until 1941 during the Yakima Valley outbreak mentioned in relation to WEE. [89] As with WEE, *Culex tarsalis* is the most important enzootic (animal) and epidemic (human) vector in the western United States. [181] Like WEE, SLE has an active mosquito-bird cycle with humans being dead-end hosts. Also like WEE, SLE outbreak investigations have revealed that the disease occurrences were associated with increased cumulative precipitation early in the year, above average mean monthly temperatures during the spring, and high vector populations. [160] How the SLE virus overwinters has not been determined. Much of the information provided about *Culex tarsalis* in relation to WEE also applies to SLE.

From 1964 to 2000, only three human cases of SLE have been reported for Idaho. All occurred in 1969. [106]

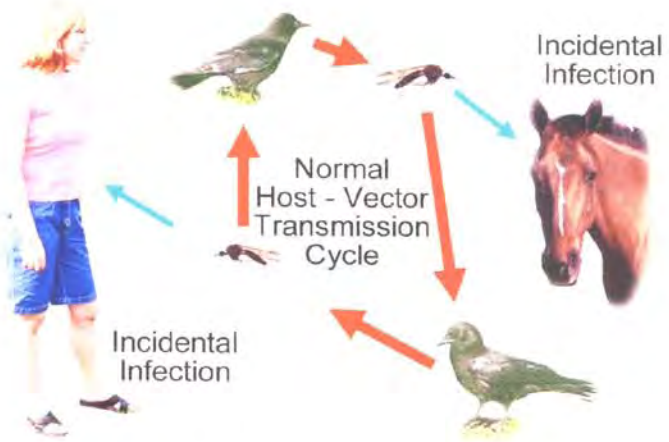


Figure 4-4. Simplified transmission cycle for Western Equine Encephalitis, St. Louis Encephalitis and West Nile Virus (normal host - vector cycle identified by red arrows and incidental infections identified by blue arrows).

West Nile Virus

West Nile virus (WNV) is another arbovirus that can cause illness in humans, horses, and birds. By the end of 2002 WNV literally stopped at the borders of Idaho. Various state agencies are actively preparing for its presence in 2003. [108] Because of the real probability of the disease occurring in Idaho, information about WNV is provided.

WNV has been an Old World arbovirus since

being isolated in the West Nile District of Uganda in 1937. [197] It has been reported elsewhere in Africa, as well as Europe, the Middle East, and west and central Asia. [81, 92, 167, 189] Several Old World *Culex* species, including *Culex pipiens* (Northern House Mosquito), have been identified as vectors of the disease. [81, 92, 205]

On August 4, 1999, and the days following, 62 human cases (7 deaths) and 62 horse cases of WNV were reported in four boroughs of New York City and adjacent counties, and epizootic activity in birds and/or mosquitoes were reported in three adjacent states. These human cases represented the first outbreak of WNV in the Western Hemisphere. [18, 36] In 2000, the disease increased its geographic range to include 12 states, affecting 21 humans (2 deaths) and 65 horses and other mammals. [22, 36] In 2001, the disease further increased its geographic range to include 27 states and the District of Columbia with 66 human cases (9 deaths) and 733 horses affected. [25, 36] In 2002, the disease continued to increase its geographic range to include the remainder of the United States, excluding Oregon, Nevada, Utah and Arizona, with 4,156 human cases (284 deaths) [37] and more than 14,000 horses affected. [212] In the fall of 2002, an equine case in Idaho was documented, although the horse had traveled to another affected state prior to its illness, it was impossible to rule out a locally-acquired infection.

Most human infections of WNV are asymptomatic and approximately 20 percent of infections may lead to illness. Symptoms may include fever, headache, and body aches, occasionally accompanied with skin rash and swollen lymph glands. More severe infection may be marked by headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, paralysis, and although rare, death. The case-fatality rate of persons with severe illness ranges from 3 to 15 percent, with persons over 50 years of age having the highest risk of severe disease. Normally, less than one percent of humans infected with WNV will develop severe illness. [36] The incubation period in humans (i.e., time from infection to onset of disease symptoms) is usually 3 to 15 days. [36] In 2002, human illnesses in the northern latitude states were more frequent from the second week of August to the third week of September, possibly reflecting the shift in the mosquito's host preferences. [31]

Some bird species, particularly those of the family Corvidae (crows, ravens, jays and magpies) and raptors are very susceptible to WNV. In 2002, 90 percent of WNV-infected birds were corvids and 77 percent of the crows tested were positive compared to 40 percent of all other bird species.[31] The surveillance of bird deaths has become an important epidemiologic method for detecting the spread and continued presence of WNV. (See Chapter 8 for more information on surveillance.)

As currently known, only mosquitoes transmit WNV. Based on four years of surveillance nationwide (1999 - 2002) of WNV mosquito vectors

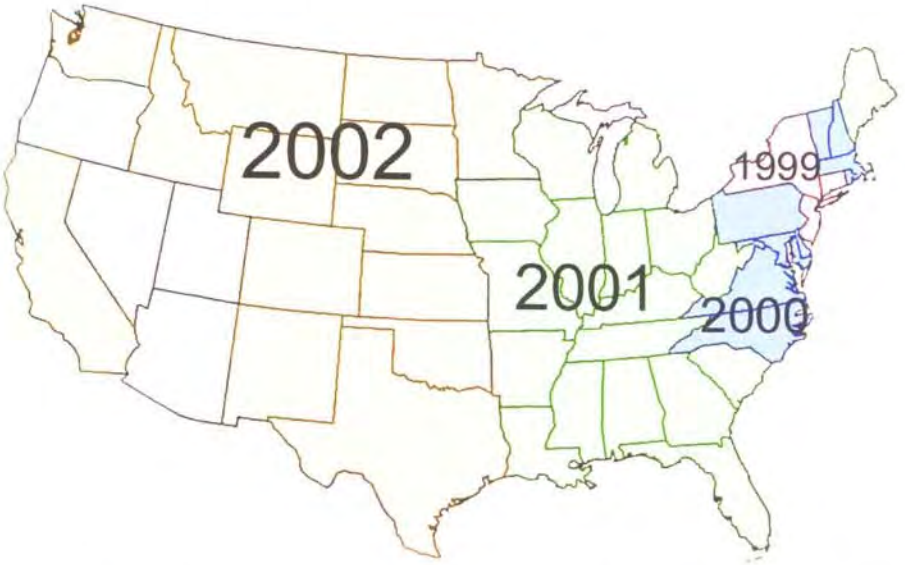


Figure 4-5. Advancement of West Nile Virus across the United States since its introduction in New York in 1999. Source: CDC.

and recent competency research, *Culex tarsalis* and *Culex pipiens* are likely to be the most important vectors of the disease in Idaho. [31, 35, 80, 188, 209, 210]

The overwintering mechanism for the WNV in the United States is uncertain at this time. Research in New York revealed WNV RNA in overwintering *Culex pipiens.* [20] Vertical transmission (transovarial) of WNV has been documented. [6] Despite the uncertainty of the overwintering mechanism, it is evident that WNV can be active for years when conditions are suitable. New York City metropolitan area has had human cases for four consecutive years. [31]

In addition to the typical mosquito-to-human transmission of WNV in 2002, the disease was also acquired from laboratory accidents involving diseased animals, [32] blood transfusions, [26, 28, 30,] organ transplantation, [26, 30] intrauterine infection, [33] and breast feeding. [27]

No antiviral or other drugs are known to be effective in the prevention or treatment of WNV infections in humans. [32] Vaccines are available for equines.

Vectors of Misery and Discomfort

The significance and economic impact attributed to the ability of mosquitoes to transmit diseases to humans and animals is enormous. However, even without considering these factors, the annoyance caused by pest mosquitoes contributes to considerable misery and discomfort. This section addresses this problem.

Anecdotal accounts from early pioneer days to the present suggest that pest mosquitoes are quite significant in parts of Idaho at times. It would probably be accurate to state that many a city official, county commissioner, health department staff member, legislator and maybe even the governor of our great state of Idaho have been contacted about "the mosquito problem." However, public opinion is diverse as it pertains to mosquitoes, with such expressions as "I can't stand being bitten, I can't even go outside"; "what's the big deal, we've always had mosquitoes"; "I'd rather have mosquitoes than be sprayed on"; and "leave them alone, they are part of nature." Regardless of the individual's position, the standard of living by Idaho citizens has progressed to a point where most individuals wish to enjoy their own backyards without taking extreme protective measures against biting mosquitoes. Since the tolerance of mosquito annoyance varies, efforts to determine an acceptable level for control purposes have been frustrating. Less than scientific surveys in four states revealed that in New Jersey, most people complain if mosquito bites exceed one in fifteen minutes; in Florida it was found that a bite rate of one per twelve minutes caused most people to rate the problem as "moderate" and one mosquito bite in one minute was "bad;" in Minnesota, the annoyance threshold level was five mosquito bites in five minutes; and in Maryland it was one mosquito bite in one minute. [123] Whatever the annoyance threshold may be for individuals and communities in Idaho, mosquito control needs to be considered.

Figure 4-6. Hungry mosquitos such as these *Ochlerotatus nigromaculis* (Irrigated Pasture Mosquito) create labor problems on the farm.

Credible literature on the economic impact of pest mosquitoes is scarce. Indirect financial loss in the animal industry has been measured and documented. There is evidence that mosquitoes cause a reduction of weight gain in beef animals and decreased milk production in dairy cattle, with losses in the millions of dollars. [97, 203] Mosquito infestations are known to create labor problems where farm help is reluctant to work in localities having serious mosquito problems. [218]

Tourism and outdoor recreation can be seriously impacted by pest mosquitoes. [71] This industry is quick to recognize the potential for decreased revenues due to mosquito problems. Visitors are known to alter their recreational choices in order to avoid the risk of being bitten by hoards of mosquitoes.

5

Idaho Mosquitoes

Idaho currently has more mosquito species and subspecies than any of the adjoining states. This chapter provides a list of the 51 mosquitos, their importance, brief notations about each, and comments pertaining to other mosquitoes that may be found in or invade the state. This list is based on the 2003 checklist of Idaho mosquitoes by Brothers and Darsie. [15] The common names provided for mosquitoes are those in general use by federal, state and mosquito abatement agencies.

The level of importance designation for the mosquitoes of Idaho is somewhat artificial since the determining factors are not the same in all parts of the state. This is particularly true as it applies to geomorphic regions, ecological life zones, climatic factors, human population densities, land use, and irrigation practices, to mention a few. There is also a lack of information for some of the less common and rare species. Considering these factors, the overall relative importance of Idaho mosquitoes may be classified as follows (modified from several authors): [76, 201]

Important - Mosquito species which are abundant, widely distributed, a serious pest or competent disease vector;

Less Important - Mosquito species which are abundant, a pest under restrictive ecological conditions and may be a disease vector; and

Unimportant - Mosquito species which may be a pest under restrictive ecological conditions, but are generally uncommon or rare, some of which may have been reported in the literature as a disease vector.

Additional comments pertaining to relative importance are provided in the notes portion of this chapter.

List of Idaho Mosquitoes

(and their importance)

Genus ANOPHELES (*An.*)

- *An. earlei* . . . . . Unimportant
- *An. freeborni* (Western Malaria Mosquito) Important
- *An. punctipennis* (Mottled-winged Anopheles) . . . . . Less Important

Genus *AEDES (Ae.)*

- *Ae. cinereus* (Little Smokey Mosquito) . . . . . Less Important
- *Ae. vexans* (Inland Floodwater Mosquito) Important

Genus *OCHLEROTATUS (Oc.)*

- *Oc. aboriginis* . . . . . Unimportant
- *Oc. campestris* . . . . . Less Important
- *Oc. canadensis canadensis* (Woodland Pool Mosquito) . . . . . Less Important
- *Oc. cataphylla* . . . . . Less Important
- *Oc. communis* (Common Snowwater Mosquito) . . . . . Less Important
- *Oc. decticus* . . . . . Unimportant
- *Oc. dorsalis* (Salt Marsh Mosquito) . . . . . Important
- *Oc. eudes* . . . . . Unimportant
- *Oc. excrucians* . . . . . Less Important
- *Oc. fitchii* . . . . . Less Important
- *Oc. flavescens* . . . . . Unimportant
- *Oc. hendersoni* . . . . . Unimportant
- *Oc. hexodontus* . . . . . Less Important
- *Oc. impiger* . . . . . Unimportant

Oc. implicatus . . . . . Unimportant
Oc. increpitus . . . . . Less Important
Oc. intrudens . . . . . Unimportant
Oc. melanimon (Wetlands Mosquito) Less Important
Oc. mercurator (Brown Woods Mosquito) . . . . . Unimportant
Oc. nevadensis . . . . . Unimportant
Oc. nigromaculis (Irrigated Pasture Mosquito) . . . . . Important
Oc. niphadopsis . . . . . Less Important
Oc. pionips . . . . . Unimportant
Oc. provocans . . . . . Unimportant
Oc. pullatus . . . . . Less Important
Oc. punctor . . . . . Unimportant
Oc. schizopinax . . . . . Unimportant
Oc. sierrensis (Western Treehole Mosquito) . . . . . Less Important
Oc. spencerii idahoensis . . . . . Less Important
Oc. sticticus (Floodwater Mosquito) . . . . Important
Oc. trivittatus . . . . . Unimportant
Oc. ventrovittis . . . . . Unimportant

Genus *CULEX (Cx.)*
Cx. boharti . . . . . Unimportant
Cx. erythrothorax (Tule Mosquito) Less Important
Cx. pipiens (Northern House Mosquito) . Important
Cx. restuans (White-dotted Mosquito) Unimportant
Cx. salinarius (Unbanded Saltmarsh Mosquito) . . . . . Unimportant
Cx. tarsalis (Western Encephalitis Mosquito) . . . . . Important
Cx. territans . . . . . Unimportant

Genus *CULISETA (Cs.)*
Cs. alaskaensis . . . . . Unimportant
Cs. impatiens . . . . . Unimportant
Cs. incidens (Fish Pond Mosquito) . . Unimportant
Cs. inornata (Winter Marsh Mosquito) . . . . . Less Important
Cs. minnesotae . . . . . Unimportant
Cs. morsitans . . . . . Unimportant

Genus *Coquillettidia (Cq.)*
Cq. perturbans (Cattail Mosquito) . . . Unimportant

Based on the importance determination for the mosquitoes listed above, 7 would be considered important, 17 would be considered less important and 27 would be considered unimportant.

Species Notes

The following notes pertaining to Idaho mosquitoes provide brief information concerning some aspects of their distribution, biology and relative importance. Range maps are modified from those presented by Darsie and Ward. [50] It is suspected that the ranges of most mosquitoes in Idaho are greater than depicted. For reference purposes, the following river systems are included on the range maps (from north to south): Spokane/Coeur d'Alene, Clearwater, Salmon, Weiser, Payette, Boise and Snake.

Genus *Anopheles*

Anopheles earlei. Based on Idaho collection records (as *occidentalis* in early years), this is a relatively rare species in the state. It has been collected in small numbers in the vicinity of Kellogg and the Upper Snake River Plain. [79] Although an avid biter, it is not known to be a vector of disease.

***Anopheles freeborni* (Western Malaria Mosquito)**. This is the most common and abundant anopheline mosquito in Idaho. The suspected malaria outbreak in Horseshoe Bend in the late 1930s is attributed to this species. [120] The female overwinters in sheltered locations and emerges in the early spring. The species is one of the first biters of the season, attacking when the air is still cold. They bite freely from dusk to dawn. Females readily enter dwellings and feed on humans. Eggs are commonly laid singly in semi-permanent water sources associated with poor irrigation practices. Water containing an abundance of algae seems to be preferred. [83] In addition to being a malaria vector, western equine encephalitis has been isolated from this species. [76]

***Anopheles punetipennis* (Mottled-wing Anopheles)**. This species is less common than *An. freeborni* in Idaho, the greatest abundance being in the Panhandle. [79, 120] The female overwinters. Preferred breeding sites appear to be cool, partly shaded, and slowly moving fresh water where there is an abundance of emergent vegetation. However, breeding in artificial containers has been observed. [79] The species appears to be an outdoor mosquito and seldom enters houses for a blood meal. [83] Although it is not considered an important vector of disease, West Nile virus has

recently been isolated from this species in the eastern United States. [22]

Genus *Aedes*

***Aedes cinereus* (Little Smokey Mosquito).** This is a small mosquito of the woodland and open meadows and is found throughout Idaho. In some mountain areas and in the Panhandle, it is a predominant species and a pest. Breeding sites of choice appear to be shallow pools associated with willows. The species overwinters in the egg stage and is considered single-brooded. Females prefer to bite in shaded areas and one need only walk a few yards into open areas to be entirely free from attack. [83]

***Aedes vexans* (Inland Floodwater Mosquito).** This is the most important floodwater mosquito in Idaho. Breeding sites produce great numbers of these fierce biters and because of their dispersal range, their influence can be felt over a large area. Winter is passed in the egg stage and there are generally one or more broods (multi-brooded) per season, but not all eggs hatch with a single flooding. [66] Therefore, irrigation practices with poor drainage suit this species well. When breeding is a result of overflow along river bottoms, *Oc. sticticus* can often be found associated with this mosquito. Females prefer feeding in the shade during the day and are extremely active at dusk. This mosquito is capable of transmitting western equine and St. Louis encephalitis viruses. [170] West Nile virus has been isolated from this species in the eastern United States. [22]

Genus *Ochlerotatus*

***Ochlerotatus aborigines*.** This northern species has been found in limited numbers in the Panhandle part of the state. Larvae are found in snowpools in wooded and semi-wooded areas. [76] Females are not considered to be aggressive biters. Overwintering occurs in the egg stage.

***Ochlerotatus campestris*.** Although generally a single-brooded species that breeds early in the season, additional broods may occur when the breeding site is reflooded. [154] Preferred breeding sites include pools from melting snow, rain, and irrigation waste water which are alkaline. [83] Larvae often hang suspended between the surface and bottom of the pool. [154] Females are aggressive and bite anytime during the day, but are most active in the morning and evening hours. The species over-winters in the egg stage.

***Ochlerotatus canadensis canadensis* (Woodland Pool Mosquito).** This is a relatively common subspecies in northern Idaho and less so southward. A primary brood emerges in the early spring with additional smaller broods during the season when conditions are favorable. [17] Breeding sites of choice seem to be shaded snowmelt pools containing fallen leaves. Females are persistent biters in shaded locations. Overwintering occurs in the egg stage. West Nile virus has been isolated from this subspecies in the eastern United States. [24] This mosquito has also been incriminated in the transmission of the canine heartworm. [48]

***Ochlerotatus cataphylla*.** Although breeding sites of this mosquito are found in timbered areas at high elevations in the state, it is more often found in open, grassy snowmelt pools in sagebrush valley and foothill areas. [154] Not particularly abundant, females of this species are strong fliers and avid biters, and can be a pest in recreational areas near breeding sites. [153] It is a single-brooded species. Overwintering occurs in the egg stage.

***Ochlerotatus communis* (Common Snowwater Mosquito).** This is a species of the forested areas of Idaho and most common from the central portion of the state and northward. It is a single-brooded species and prefers breeding in shaded or partially shaded pools. Females are persistent biters in shaded areas during the day and at dusk. They can be an important pest in recreational areas close to breeding sites. Their average dispersal is generally less than one-fourth mile. [144] Overwintering occurs in the egg stage.

Ochlerotatus decticus. This species was first discovered in Idaho in Valley County in 2002. [15] Little information is available about this species in the state, other than the description of the larval site, which was a shallow, side-stream, open pool of snowmelt water containing dead sedge, at an elevation of 6,365 feet. The species is likely a single-brooded species and overwintering occurs in the egg stage. Bites of the female have been reported as being "scarcely noticeable." [195] The species is undoubtedly rare in this state.

***Ochlerotatus dorsalis* (Salt Marsh Mosquito)**. This is an important pasture and field mosquito in Idaho. It is a vicious biter and is often a source of complaints many miles from the breeding site. The larvae of this species occurs in a great variety of habitats, including both fresh and strongly alkaline water. Habitats associated with irrigation produce large populations of this species since temporary grassy pools exposed to direct sunlight are a preferred larval habitat. [83] As many as ten successive broods in a single season may be common. [174] This species is a very strong flier and migrates many miles from the breeding site; as far as 22 miles have been reported in Utah. [174] Natural infections of western equine and St. Louis encephalitis have been reported for this species. [76] Recent vector competency research reported the species to potentially be a moderately efficient vector of the West Nile virus. [80]

Ochlerotatus eudes. Although this is a newly reported species for Idaho, [15] it has been found near the state's eastern border. [149, 136] Therefore, its pesence in Valley County should be of no surprise. This species was collected at the same time and in the same breeding pool mentioned for *Oc. decticus*. The species is closely related to *Oc. excrucians* and *fitchii*, which were also in the same pool. Like the latter two, *Oc. eudes* is a single-brooded species and overwinters in the egg stage. Until further information is available about this species in the state, it should be considered rare.

Ochlerotatus excrucians. This is a widely distributed species in the state from moderate to high elevations and may be common locally. The species is single-brooded and larvae may be found in snowmelt pools in meadows and open marshes. Females bite in the shade of the woods, but are most active in the evenings. Overwintering occurs in the egg stage. The species is of moderate importance in areas where breeding occurs.

Ochlerotatus fitchii. Closely related to the preceding two species, *Oc. fitchii* is found throughout the state in greater numbers. The species is single-brooded and larvae may be found in a variety of temporary and semi-permanent habitats containing emergent vegetation. Females are vicious biters during the day as well as night. [157] The average dispersal from breeding sites is less than one-half mile. [144] Overwintering occurs in the egg stage. The species is of moderate importance.

Ochlerotatus flavescens. This large, pale-colored mosquito is widely distributed in Idaho, although the numbers are generally few. It is a single-brooded species and larvae may be found in a variety of aquatic habitats in river plains. Females can be a nuisance when in the vicinity of breeding sites. Overwintering occurs in the egg stage. The species is of minor importance.

Ochlerotatus hendersoni. This is a treehole mosquito. Although the species may be distributed throughout much of the state (primarily in riparian habitats), it is rarely encountered. In Utah, the species has been collected with *Oc. sierrensis*. [153]

Ochlerotatus hexodontus. This mosquito is found in the mountainous areas of the state. It is a single-brooded species and larvae may be found in shallow, grassy, snowmelt pools and marshes in open areas, as well as smaller pools in the forest. Females may be abundant locally and are avid biters in the shade. [200] Overwintering occurs in the egg stage. The species can be of moderate importance in recreational areas.

Ochlerotatus impiger. As a high mountain species, this mosquito is an annoyance primarily to those who frequent such elevations. [153] It is a single-brooded species and the larvae may be found in shallow, grassy, snowmelt pools in open meadows. Overwintering occurs in the egg stage. The species is of minor importance.

Ochlerotatus implicatus. This is a single-brooded species that breeds in higher elevations of the state. Larvae may be found in overflow pools along streams, or in grassy pools among willows. Females readily bite in shaded areas and on cloudy days. Overwintering occurs in the egg stage. It is considered unimportant as a pest. [76, 149]

Ochlerotatus increpitus. This is a common snow pool species that is found throughout the state. It is a single-brooded species and larvae may be found in snowmelt pools in open meadows and depressions in semi-wooded areas. Swarms of females cause great annoyance to humans and animals in woods and shaded locations as well as on cloudy days. [200] This species frequently invades urban areas. Overwintering occurs in the egg stage. The picture on the cover of this guide is of this species.

Ochlerotatus intrudens. A single-brooded species, this mosquito's preferred breeding habitat is in forest pools resulting from snowmelt. Females are avid biters both day and night, and will enter dwellings to feed. [57, 149] Overwintering likely occurs in the egg stage. This mosquito does not occur in significant numbers to be of any importance.

Ochlerotatus melanimon **(Wetlands Mosquito)**. This mosquito closely resembles *Oc. dorsalis* and often shares the same breeding sites. Like *dorsalis*, it is a multi-brooded species, but prefers breeding sites with fresher water. Larvae may be found in overflow pools along larger streams and rivers, irrigated meadows and pastures. Although females will bite in shaded areas, they are more aggressive at dusk. Overwintering occurs in the egg stage. Western equine encephalitis and California encephalitis viruses have been isolated from this species. [90, 91] It is suspected to be the most important vector of western equine encephalitis in Utah. [183] Recent research reported that *Oc. melanimon* may have the potential to act as a secondary or bridge vector for West Nile virus. [80]

Ochlerotatus mercurator. Previously known as *Aedes stimulans*, this species is generally considered a mountain mosquito. However, larvae have been collected from shaded habitats along streams of several broad valleys at lower elevations. [84] It is a single-brooded species and overwintering occurs in the egg stage. It is apparently uncommon in Idaho and not considered important.

Ochlerotatus nevadensis. Previously considered a subspecies of *Oc. communis*, the distribution of this species in the southern part of Idaho is not fully understood. Collections of this species in the Grand Teton National Park and in Utah would suggest that the species occurs, at least, in the southeastern part of the state. [136, 153] Larvae are found in small snowmelt pools in forested areas. [152] Until further information is available about the species in Idaho, it should be considered of little importance.

Ochlerotatus nigromaculis **(Irrigated Pasture Mosquito)**. This is a common pest mosquito of the agricultural communities and surrounding areas of southern Idaho. It is a ferocious biter, inflicting a painful bite. It is a strong flier and may migrate several miles from its breeding site. Swarms of these daytime biters can bring normal outdoor activities to a virtual standstill. The primary habitat of this species has been largely artificially created by agriculture, with irrigated pastures being one of the favorites. The open, sunlit pools of waste irrigation water allows rapid development of the larvae. The winter is passed in the egg stage with hatching occurring within hours of flooding. Development is extremely rapid, with a life cycle of less than seven days. *Oc. nigromaculis* is able to produce a brood following each irrigation cycle (multi-brooded). Breeding sites can produce astronomical numbers of mosquitoes. One alfalfa field in the Treasure Valley had an average of more than 5,000 *nigromaculis* larvae per square foot of breeding area. [13] Larvae are present from May until late September. Overwintering occurs in the egg stage. This mosquito species is capable of transmitting western equine, St. Louis and California encephalitis viruses. [170]

Ochlerotatus niphadopsis. This plains, valley and foothills mosquito can be abundant locally in eastern Idaho. [84] It is a single-brooded species and larvae may be found more abundantly in shallow alkaline pools. Females are vicious biters anytime during the day and particularly during the evenings. Overwintering occurs in the egg stage. This species is of moderate importance.

Ochlerotatus pionips. Southern Idaho appears to represent the southernmost limit of the range of this widespread but rare species. It is a single-brooded species and larvae may be found in larger, deeper, semi-permanent and temporary forest pools. [152] Females have not been observed biting humans. [152] Overwintering is in the egg stage.

Ochlerotatus provocans. Previously known as *Aedes trichurus*, this is an uncommon mosquito in Idaho. Breeding sites occur in snowmelt pools in and adjacent to wooded areas of the central and northern parts of the state. The species is single-brooded and overwintering occurs in the egg stage. The mosquito is of minor importance.

Ochlerotatus pullatus. This woodland mosquito is chiefly confined to the higher elevations and northern latitudes of the state. It is a single-brooded species and the larvae may be found in snowmelt pools in a variety of habitats. Depressions left by the roots of fallen trees are a frequent larval source. [152] Overwintering occurs in the egg stage. Females are aggressive and can be bothersome when in the vicinity of breeding sites. [153]

Ochlerotatus punctor. A northern rare species, *Oc. punctor* has only been reported in the upper counties of the Panhandle of Idaho. It may also exist along the eastern border of the state, since it has been collected in Yellowstone National Park and Grand Teton National Park. [136, 152] It is a single-brooded mosquito and preferred breeding sites are small snowmelt pools in the forest. Females are persistent biters when in the vicinity of breeding sites. The species overwinters in the egg stage. Because it is rarely encountered, it is of little importance.

Ochlerotatus schizopinax. A rare species throughout its range, it has been collected in the southern part of the state. The mosquito is a single-brooded species and larvae may be found in pools of shallow water with high organic content. Females are not known to bite humans. [153] Overwintering is in the egg stage. This mosquito is of no importance.

Ochlerotatus sierrensis (Western Treehole Mosquito). This species has been considered generally unimportant in Idaho because of its restrictive breeding habitat. However, the species may be considered a pest mosquito in residential areas located in riparian and mixed woodland communities along rivers. It breeds in treeholes (even stumps) that contain sufficient water for larval development as well as artificial containers, rock pools, automobile tires and wooden receptacles stored or discarded under the trees in the mosquitoes' habitat. Females are persistent biters in shaded areas during the day and at dusk. They appear to have a restrictive flight range and do not wander far from their preferred habitat. Overwintering may occur as larvae or in the egg stage. This species is of interest because females are important vectors of the canine heartworm. This disease is locally common in northern Utah and may be important in Idaho. [87, 191]

Ochlerotatus spencerii idahoensis. Once considered a species, this is a distinctive western form of *spencerii*. [156] It is an annoying mosquito of the low mountain valleys and plains, and found throughout Idaho. It is a single-brooded mosquito and larvae are found in snowmelt pools in open meadows, stream overflow pools and roadside ditches. Females are strong fliers and may be found some distance from their breeding sites. They bite persistently in shaded areas during the daytime and at dusk. [84] The species overwinters in the egg stage. This is an important pest mosquito in the state.

Ochlerotatus sticticus **(Floodwater Mosquito)**. As the common name implies, this is an important floodwater species found throughout Idaho. It breeds in large numbers in floodwater

pools in the bushy bottomlands along rivers. It is a single-brooded species and eggs have been known to survive (in the absence of flooding) for at least three seasons. [161] Females are strong fliers and disperse many miles from the breeding area. It is a serious pest to humans and livestock, biting in shaded areas during daylight hours and at dusk and dawn. They readily enter dwellings to obtain a blood meal. [153] The species overwinters in the egg stage. This species is capable of transmitting western equine and St. Louis encephalitis viruses. [76]

Ochlerotatus trivittatus. The collection of this species in Canyon and Owyhee Counties on June 27, 1945 represented a significant western extension of its range. [84] It is a single-brooded species. Larvae are known to exist in overflow pools along rivers and streams and in rain pools. Although females inflict painful bites and are extremely persistent when seeking blood meals, they are unimportant in Idaho because of their rarity. The species overwinters in the egg stage. West Nile virus has been isolated from females of this mosquito in the East. [22]

Ochlerotatus ventrovittis. This uncommon mountain mosquito is known to exist in eastern Idaho. [76] It is a single-brooded species and eggs hatch quickly as snow melts. Unlike other *Ochlerotatus* mosquitoes, the larvae occur in rivulets and small pockets or depressions through which water is continually moving due to snowmelt. [152] Females are aggressive biters and may be abundant in the vicinity of breeding sites. Overwintering is in the egg stage.

Genus *Culex*

Culex boharti. This mosquito is uncommon throughout its range. In Idaho, it has been reported from Valley County. [116] Preferred breeding sites are streambed habitats which are partially shaded and with an abundance of emergent vegetation and algal growth. [116] Females are not known to bite humans. [17]

***Culex erythrothorax* (Tule Mosquito)**. This reddish mosquito is not common in Idaho. It is a multi-brooded species and eggs are laid on the water surface in rafts. Larvae are generally found in semi-permanent or permanent marshes with heavy growths of emergent vegetation. Females become active at dusk, but will bite humans readily during the day when their habitat is invaded. They are considered opportunistic feeders and feed on a variety of animals. [181] It has been reported that the species most likely overwinters as larvae, but this has not been confirmed in Idaho. [40, 115] The species may serve as a vector of West Nile virus. [80]

***Culex pipiens* (Northern House Mosquito)**. Because of its close association with human habitation, this nondescript mosquito is considered domesticated. It is common throughout the state. In mature communities with an overgrowth of vegetation, the species can be very abundant. It is multi-brooded and eggs are laid in rafts in temporary and permanent pools, retention ponds, open septic tanks and in numerous artificial containers. Breeding water with a high organic content is preferred. In numerous catchbasins in one densely populated community of Ada County, as many as 300 to1,200 larvae per square foot were found. [13] This mosquito does not migrate far from its breeding area and feeding begins shortly after sunset and most feeding is completed by midnight. [103] Although birds are the host of choice, feeding on humans in Idaho has been reported. [93, 148] Females overwinter. *Cx. pipiens* is a vector of western equine and St. Louis encephalitis viruses as well as organisms of a number of animal diseases. [17] Recently, the species has been incriminated as being the primary vector of West Nile virus in the eastern United States. [22] Research reported in 2002, suggests that this species will be an important vector of the virus among birds in urban settings in the West. [80]

***Culex restuans* (White-dotted Mosquito)**. This mosquito is uncommon in Idaho and has been reported in only a few counties in the southern part of the state. It is multi-brooded and eggs are laid in rafts in a variety of habitats, including permanent

and semi-permanent pools with high organic content and artificial containers. Females are known to occasionally feed on humans, but birds are the primary host. [17, 103] Overwintering is as adult females. Although not considered important in Idaho, western equine and St. Louis encephalitis viruses have been isolated from the species. [130, 158] West Nile virus has been isolated from the mosquito in the eastern United States. [21]

***Culex salinarius* (Unbanded Saltmarsh Mosquito)**. The common name of this uncommon Idaho mosquito is not applicable to the population in the state; the name was possibly derived from its abundance in salt marshes of the East Coast. It is a multi-brooded species and eggs are laid on the water surface in rafts. Breeding occurs in a wide variety of aquatic habitats including grassy pools, ditches, marshes and artificial containers. [76] It is reported as an opportunistic feeder. [188] In Utah, females readily bite humans and enter dwellings. [157] Adult females overwinter. West Nile virus has been isolated from this species in the eastern United States. [21]

***Culex tarsalis* (Western Encephalitis Mosquito)**. This is a common, pestiferous and important mosquito of Idaho. It is considered to be the most adaptable of any of the *Culex* species in the Western States. [115] The species is found throughout the state to an elevation of 9,000 feet. [115] Unfed females overwinter in protected places such as cellars, outbuildings, culverts, rock piles, animal burrows and other sheltered locations. Upon emerging, the female seeks a blood meal to mature her eggs. Preferred breeding sites include open, sunlit temporary to semi-permanent bodies of fresh or polluted water, marshes, waste irrigation water, ditches, retention ponds and even artificial containers in rural as well as urban areas. Several broods are produced per season. Flight dispersal distance from breeding sites have been reported at 15 miles. [175] Females are persistent biters and under ideal climatic conditions become active one-half hour after sunset for an hour or so, with some still out till sunrise. [70] Although females prefer avian blood in the spring, they later turn to mammals and humans as a source of blood. [153] This habit makes this mosquito a very important "bridge vector" (passing a disease outside its usual cycle to other susceptible hosts). This mosquito is the most important vector of western equine and St. Louis encephalitis viruses. [76] California encephalitis virus has also been isolated from this mosquito. [76] West Nile virus was isolated from this species in 2002. [31] According to research reported in 2002, *Cx. tarsalis* has the greatest potential to amplify and maintain the West Nile virus and may be the principal bridge vector in rural agricultural ecosystems. [80]

Culex territans. Based on Idaho collection records (as *apicalis* in early years), this is an uncommon species with wide distribution. [76] Females are multi-brooded and eggs are generally laid in rafts on the water surface in permanent and semi-permanent freshwater ponds and marshes containing emergent vegetation. Females are not known to feed on humans. [153] Overwintering is in the adult stage. West Nile virus has been isolated from this species in the East. [31]

Genus *Culiseta*

Culiseta alaskaensis. This species in Idaho is represented by a single record in Blaine County. [51] The sparse occurrence of *Cs. alaskaensis* in neighboring states supports its rarity. The species is confined to the mountains at moderate elevations. [173] It has been reported as breeding in a permanent marsh. [152] Females are known to attack humans. Females overwinter.

Culiseta impatiens. *Culiseta impatiens* is another Idaho mosquito not likely to be encountered with any frequency. Females lay their eggs in rafts on the water surface of small shaded or partially shaded permanent and semi-permanent locations with considerable vegetation and organic matter. [153] Females will bite humans when their habitat is invaded and will enter dwellings in search of a blood meal. [152] Females overwinter.

***Culiseta incidens* (Fish Pond Mosquito)**. This large species is found throughout Idaho in small numbers. It is one of the first mosquitoes to greet humans in the spring. Breeding takes place in

permanent and semi-permanent pools and artificial containers in shaded or partially shaded locations. Larvae have been found in mineral spring water. Females attack humans but are rather timid feeders. The species has been observed feeding on the backs of cattle at dusk. This species overwinters as adult females. It is not as important as the following species.

Culiseta inornata **(Winter Marsh Mosquito)**. This large mosquito is abundant in Idaho and is commonly associated with poor irrigation practices. Females generally overwinter and emerge even before all the snow has disappeared. Larvae collected in the winter under ice suggests that this species may pass the winter in this stage also. [171] Females lay eggs in rafts on the water surface of a variety of permanent and semi-permanent sunlit or partially shaded pools supporting adequate vegetation. Poorly drained irrigated areas produce large populations of these mosquitoes. *Cs. inornata* is often found in habitats with *An. freeborni* and *Cx. tarsalis*. [76] Although females bite humans, they are not persistent biters; they prefer large mammals. Females have been found with natural infections of the California encephalitis virus. [152] The species is a laboratory-confirmed vector of western equine and St. Louis encephalitis viruses. [170] In 2002, West Nile virus was isolated from this mosquito. [31]

Culiseta minnesotae. This is a rare species with wide distribution in Idaho. Larvae have been collected in pools with emergent vegetation and heavy algal growth. [76] Females apparently do not feed on humans and the species is considered unimportant in the state. [153]

Culiseta morsitans. This is another rare species of the genus known to exist in Idaho. Unlike the other Idaho *Culiseta* species, the egg rafts are laid on damp soil above the water level of their breeding habitat. [122] Breeding habitat of the species includes marshy areas of permanent or semi-permanent pools where larvae tend to concentrate at bases of grass clumps. [153] Females and larvae may both overwinter. [122] Birds are the preferred blood meal host and they are not known to feed on humans. [153]

Genus *Coquillettidia*

Coquillettidia perturbans **(Cattail Mosquito)**. The aquatic stage of this uncommon Idaho mosquito is unique. Larvae attach themselves to underwater parts of emergent vegetation and obtain oxygen through the plant tissue. They do not need to come to the surface to respire. Eggs are laid in rafts on the water surface of permanent water in ponds, marshes and log ponds containing emergent vegetation. It is expected that the species has no more than one brood a season. [170] Females are aggressive biters, but in most areas they are not numerous enough to be a significant pest. [153] Overwintering is in the aquatic stage. West Nile virus has been isolated from this species in the Eastern States. [25] However, it is considered an incompetent vector of the disease. [188]

OTHER MOSQUITOES

New state records for *Oc. decticus* and *eudes* [15] and the invasion of exotic species in neighboring states exemplifies the possibility of other mosquitoes existing in Idaho. The following species should be considered:

Native Mosquitoes

Culex stigmatosoma **(Banded Foul Water Mosquito)**. This species has been reported as far east as Walla Walla County in Washington. [76] Similar conditions exist in the Lewiston area of Idaho. Typically, the mosquito breeds in water containing considerable organic matter, such as log ponds, wood chips in standing water, street catchbasins, and industrial waste. This species superficially resembles *Cx. tarsalis*, but is easily distinguished by the rounded central spots on the underside of the abdomen. Females do not favor feeding on humans and the species would be considered unimportant if found in the state.

Ochlerotatus diantaeus. This is a northern species that may be found on Idaho's eastern border. It has been collected in limited numbers in several localities in the Rocky Mountains of Wyoming and Montana. [136, 152] Records of this species indicate a southern extension to its range. If found

in Idaho, the mosquito would be considered unimportant.

Psorophora signipennis. This is a rare mosquito found in the desert areas of Utah, including the northern part of the state. [152] The species has the potential of existing in the extreme south central part of Idaho. Because of its rarity, it would be considered unimportant.

Exotic Mosquitoes

Aedes albopictus **(Asian Tiger Mosquito)**. This mosquito was first discovered in the continental United States in Texas in 1985. It probably entered the United States in shipments of used tires from Asia. Since then, the species has spread to more than two dozen states. [135] In 2001, the mosquito was introduced to several western states, including neighboring Oregon and Utah, in shipments of "Lucky Bamboo" (*Dracaena sp.*), a popular ornamental house plant. [133, 150] The mosquito breeds in water contained in a wide variety of natural and artificial containers, such as treeholes, flower pots, cemetery urns, discarded cans, jars, tires, etc. This mosquito can be easily identified by the contrasting silvery-white and dark scales. The legs have basal white bands. Abdominal basal white bands are narrow and the dorsal surface of the thorax has a narrow medial longitudinal line of white scales. Females bite during the day. West Nile virus has been isolated from this species. [22]

Ochlerotatus japonicus **japonicus (Asian Bush Mosquito)**. Although this mosquito has become established in the eastern part of the country, it was first reported in the western United States in Washington in 2001 and has subsequently become established in several counties. [215] Like the preceding species, this mosquito also breeds in a wide variety of natural and artificial containers. Eggs are resistant to drying and can survive for months without water. Females are daytime feeders and will bite when their habitat is invaded. [165] West Nile virus has been isolated from this species. [21]

Since it is beyond the intent of this work to go into more detail about the individual species, the references cited herein should be consulted for more specific information. If the reader obtains relevant information about any aspect of the biology or distribution of these insects in Idaho, documentation and the sharing of such information is encouraged. The preservation of voucher specimens is also encouraged. Techniques for the preservation of mosquitoes is included in Chapter 8.

6

Mosquito Control

It is a fact that there is no mosquito control or management program that can eliminate all mosquitoes. Nevertheless, efforts must be made by individuals, property owners and responsible agencies to keep mosquitoes at bay or at an acceptable level to promote well-being and reduce the potential for mosquito-borne diseases. This chapter addresses these areas.

Personal Protection

In any type of situation involving mosquitoes, individuals must assume the primary responsibility, as the first line of defense, for personal protection and the protection of family members. This includes the following:

- Avoid mosquitoes by not being outside when they are active. This is particularly important when mosquito-borne disease activity has been reported in the area. As mentioned in Chapter 4, the primary mosquito vector of viral diseases in Idaho becomes active about one-half hour after sunset for a few hours or so, with some active until sunrise. [70] Research has demonstrated that avoidance is effective in reducing infection. [70, 178]
- Ensure that doors and windows are screened and in good repair.
- Use a fly swatter or approved aerosol space sprays for killing mosquitoes found indoors. Sprays are available at most stores; use only according to container instructions.

Figure 6-1. Mosquitoes can be kept out of the home by properly screening all openings.

- Wear shoes, socks, long pants, and a long-sleeved shirt when outdoors for a long period of time or when mosquitoes are most active. Clothing should be light colored, made of tightly woven material, and be loose fitting in order to keep mosquitoes away from the skin. [21]
- Use mosquito netting when sleeping outdoors or in an unscreened structure. Consider using netting for protecting infants when outdoors.
- Consider the use of mosquito repellents; use according to container instructions. General information about using repellents is provided by the EPA. [60] A summary of the effectiveness of mosquito repellents tested and reported in the New England Journal of Medicine is provided below: [69]

Product	Active Ingredient	Minutes of Complete Protection
Off! Deep Woods	23.8% DEET*	302
Sawyer Controlled Release	20% DEET	234
Off! Skintastic	6.7% DEET	112
Bite Blocker for Kids	2% Soy oil	95
Skin-So-Soft Bug Guard Plus	7.5% IR3535	23
Natrapel	10% citronella	20
Herbal Armor	12% citronella 2.5% peppermint oil 2% cedar oil 1% lemmongrass oil 0.05% geranium oil	19
Green Ban for People	10% citronella 2% peppermint oil	14
Buzz Away	5% citronella	14
Skin-So-Soft Bug Guard	0.1% citronella	10
Skin-So Soft Mois-turizing Sun Care	0.05% citronella	3
Gone Original Wristband	9.5% DEET	0.3
Repello Wristbande	9.5% DEET	0.2
Gone Plus Repel-ling Wristband	25% citronella	0.2

* DEET is N, N-diethyl-3-methylbenzamide

Consumer Reports (June 2000, pp. 14 - 17) also lists a number of mosquito repellents and their effectiveness. Some products were reported to have longer protection than Off! Deep Woods® listed above, however, all contain DEET.

Figure 6-2. While engaged in outdoor activity when mosquitoes are about, repellents can provide some protection.

Mosquito Control at Home and at Work

In addition to personal protection, there are other things property owners can do to reduce mosquito populations on their property. This section pertains to the control of mosquito breeding and information on adult control.

Mosquito Breeding

All property owners (homeowners, businesses and governmental agencies) should be engaged in frequent general inspections of the property under their responsibility. With regard to mosquito control, the inspection process should include frequent checks for mosquito breeding during the warmer months of the year. When found, the breeding source should be eliminated or controlled. The following potential breeding sites are identified

according to community environments, businesses and public agencies.

In urban areas, the following potential breeding sites for *Culex pipiens* (Northern House Mosquito) are of importance (particularly in more mature neighborhoods): rain gutters containing water and leaves, undrained swimming and wading pools, boats and wheelbarrows containing water, barrels and old oil drums, used paint cans and miscellaneous utility containers, holes and depressions containing water, food and beverage containers, flower vases and urns, birdbaths, ornamental fountains and pools, pet waterers, drain pans under potted plants containing water, unused tires and a multitude of impervious trash that can hold water.

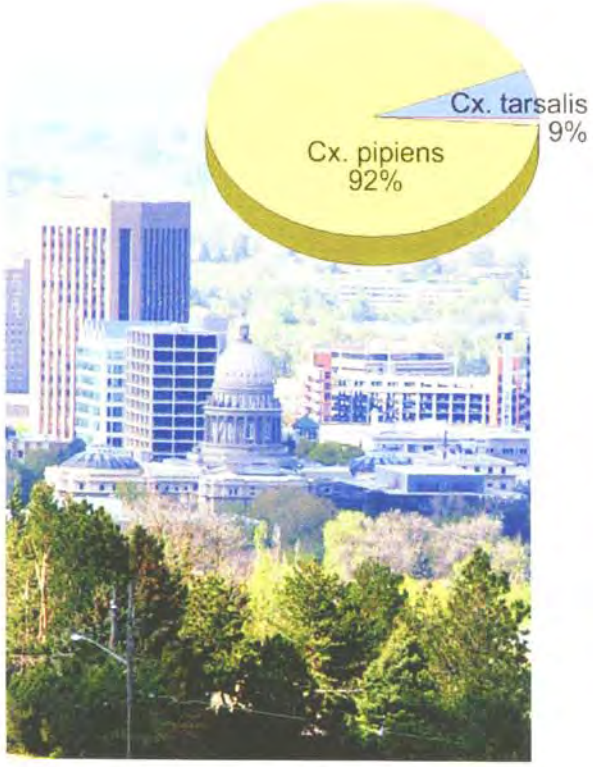


Figure 6-3. In the north end of Boise, *Culex pipiens* is the most common mosquito. [13]

Although *Culex pipiens* prefers to feed on birds, they occasionally feed on humans. Because of their potential as a disease vector, it is not good to have large populations of this mosquito in environments of dense human populations, simply because they "infrequently bite humans." [3]

In suburban areas, *Culex tarsalis* (Western Encephalitis Mosquito), in accompaniment with *Culex pipiens*, significantly increases the public health risk in this environment. The breeding sites mentioned for urban areas as well as the following are of importance: standing water from sprinkling and flood irrigation, and retention ponds and ditches. These examples can be major sources of mosquitoes for subdivisions.

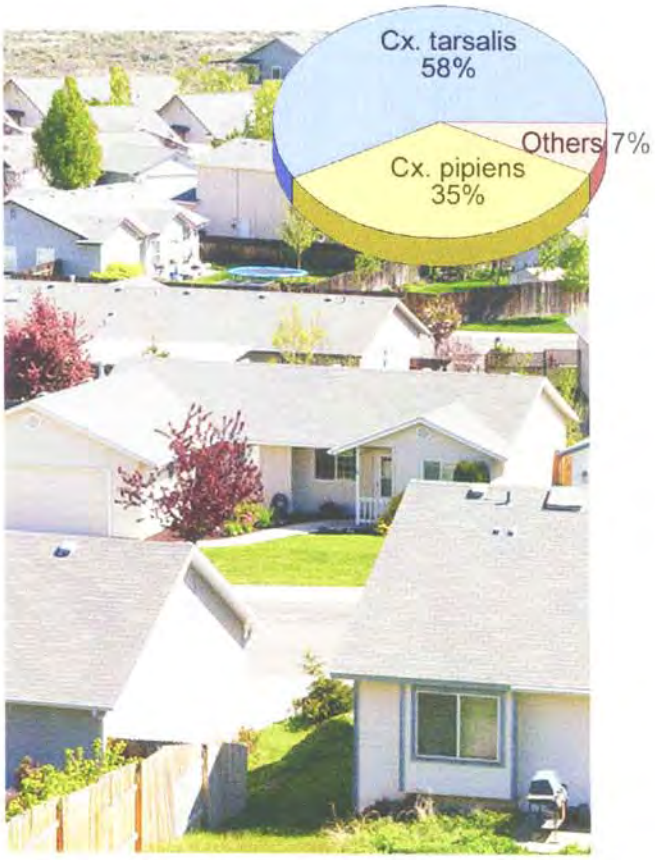


Figure 6-4. In suburban Ada County, *Culex tarsalis* becomes the dominant species, with an increase of day-biting *Ochlerotatus* and *Aedes* species. [13]

As mentioned elsewhere in this guide, *Culex tarsalis* goes through a host preference change in midsummer and will readily feed on humans. [176] Because of the potential of this species as an important disease vector, it is not good to have large populations of this species in residential areas.

In rural areas, mosquitoes of significance include the above-mentioned species and other species of *Culex*, *Culiseta*, *Aedes* and *Ochlerotatus*. Potential breeding sites are more numerous as well. The breeding sites mentioned for the previous community environments as well as the following are of importance: on-field irrigation sources such as fields, forage crops and pastures; off-field irrigation sources such as seeps from irrigation ditches;

drainage ditches; wastewater lagoons; depressions; farm ponds; etc.

Figure 6-5. In rural areas of Ada County, *Culex tarsalis* can be the dominant species, with a large population of day-biting *Ochlerotatus* and *Aedes* mosquitoes. [13]

Commercial and industrial areas present potential conditions for mosquito breeding, particularly for *Culex tarsalis* and *Culex pipiens*. Of significance are outdoor storage areas containing equipment, parts, materials, and other water-holding items mentioned in the previous environments; wastewater lagoons; seepage areas; depressions containing water and retention ponds.

Municipal and county sites, land, streets and roadways present situations for mosquito breeding. Significant breeding sites for *Culex pipiens* are street gutters, catchbasins, storm drains and roadside ditches containing organic matter; parks; and outdoor storage and equipment yards with situations mentioned in previous environments. The significance of these sites becomes increasingly important in areas of dense human populations (see discussion for urban areas).

With the increasing popularity of ornamental fountains and pools, private ponds and retention ponds, more permanent mosquito breeding sites may exist in residential areas and businesses. Few mosquito control solutions are available to the property owner in these situations. A popular solution in many parts of the country is the utilization of the Western Mosquitofish *(Gambusia affinis)*, a small surface-feeding minnow (discussed elsewhere in this chapter).

Chemical and biological control methods for mosquito breeding by the property owner is mostly restricted. Currently, the most popular and approved choice is the use of Mosquito Dunks® and similar products. These are non-chemical products containing a bacteria that attacks only immature mosquitos and their close relatives. It is harmless to humans, pets and fish when used according to container instructions (see Chapter 10 for purchasing information).

Figure 6-6. Mosquito Dunks® being placed in a pond for mosquito control.

Adult Control

Female mosquitoes seeking a blood meal often fly some distance from their breeding area. They do not respect any boundaries and they are continually on the move. This activity makes them more difficult to control by the property owner. Other than using the repellents mentioned above, adult mosquito control on the property is limited. Temporary control for special events can be obtained by using various commercial space sprays and foggers obtained at garden centers and other retail outlets. Using these products presents certain liabilities when not used according to label instructions. New commercial "attract and kill devices" using CO^2 and octenol are becoming increasingly popular. The services of local pest control operators are also available.

The following mosquito control products and methods have been found to have limited or no value:

- Certain plants have been marketed as being able to repel mosquitoes. Those tested provided no repellency. [124, 41]
- Citronella candles, torches, coils and incense provided 42% fewer bites than controls; ordinary candles reduced bites by 23%. [117]
- Ultrasonic electronic devices do not work against mosquitoes. [131]
- Bug "zappers" which electrocute insects kill fewer than 5% of mosquitoes; most insects killed by zappers are beneficial. [68]
- Encouraging natural predation of mosquitoes by setting up bird or bat houses is ineffective. Mosquitoes make up less than 1% of the bat's diet. [131] Having bat houses and bats close to human habitation presents the potential for other health risks.

Self-help Promotions

A component of the mosquito control effort is education. Frequently, efforts are made to inform the public and other property owners as to where mosquitoes may breed on their property. A type of "self-help" program is established and property owners are encouraged to check and eliminate any breeding sites found. Such information promotes an understanding of the mosquito's biology and the simplicity of control of some breeding sources when found, as identified in this and previous chapters. However, as with all matters requiring human response on a voluntary basis, the degree of interest and action varies. In order to have a reasonable degree of success with "self-help" mosquito control activities, the program must include, in addition to media coverage, some aspect of personal contacts, distribution of informative flyers, public meetings and backyard or site inspections. [118] Also, it is very important to have the knowledge that such "self-help" promotions will likely make an impact on the mosquito problem. It is critical to have some understanding about the different types of mosquitoes and knowing their biology before advocating specific types of "self-help" control efforts. Recommending inappropriate mosquito control activities may do little for abating a neighborhood or community problem, and may reduce the credibility of the recommending agency.

Organized Community Mosquito Control

Despite all that individuals and property owners can do to control mosquitoes, the result and outcome is sometimes less than satisfactory for a variety of reasons. If the problem is widespread, city and county officials, state legislators, health departments and other agencies are often contacted to do something about the "mosquito problem." When the interest becomes great enough, an organized community mosquito control effort is often put in place, to temporarily respond to a current or recurring problem. Serious interest in ongoing mosquito control programs has resulted in the formation of mosquito abatement districts (see Chapter 7).

Most pesticides used by governmental agencies, mosquito abatement districts and pest control operators are of the restricted-use type and require application by a licensed individual (regulated by the Idaho Department of Agriculture - see Chapter 10).

Adulticides

Regardless of how an organized community mosquito control program is initiated, the first order of business is to do something to quell the complaints and concerns of citizens. This is usually in the form of a spraying or fogging program to kill adult mosquitoes. Although popular, the use of

adulticides is controversial. It is very important to keep the public informed about spraying and fogging schedules. Examples of some adulticide applications currently used in mosquito control programs are as follows:

Ultra-Low-Volume Sprays. Adulticides are typically applied as an ultra-low-volume (ULV) spray where small amounts of insecticide are dispersed as very small droplets, usually less than 20 microns in size, depending on the method of application (pollen grains are about 50 microns). Application is made when mosquitoes are active. The ULV spray drifts through areas where mosquitoes are flying and kills them. Two types of adulticides commonly used are naled and malathion. These adulticides are organophosphorus compounds which have been mainstay insecticides for more than four decades. They pose little risk to humans when used according to label instructions. [61, 62]

Figure 6-7. Ultra-low-volume (ULV) equipment belonging to the Southwest Ada County Mosquito Abatement District is used for adult mosquito control.

Three very popular synthetic pyrethroid insecticides are permethrin, resmethrin and sumithrin. These products act in a similar manner to natural pyrethrins, which are derived from chrysanthemum flowers. When used according to label instructions, these insecticides pose little risk to humans. In the environment, however, if used inappropriately, they are toxic to fish and bees. [63]

Thermal Fogs. Thermal foggers are devices that use heat to produce a highly visible fog from fog oil which contains an insecticide. Fogs are smoke-like and will stay suspended in the air longer than cold sprays since the droplet size is smaller. Thermally generated fog has greater penetration ability in dense vegetation as opposed to sprays. Insecticides used for ULV applications can also be used for thermal fogs. The same health risks and environmental impacts apply. In addition to thermal fogs, there are **cold fog** applications. Cold fog is produced by a mechanical breakup of the spray concentrate.

Barrier Treatments. Barrier treatments with chemicals that have residual characteristics are becoming increasingly popular. Particularly to individual homeowners with sizable properties where the chemicals can be applied on vegetation along a property border. Adult mosquitoes that come in contact with barrier chemicals will die. A popular product for this purpose contains the active ingredient permethrin. It is applied by mist sprayers to reduce drift. Although the product has a low human and mammalian toxicity, it is toxic to some nontarget insects, fish and aquatic invertebrates. [63]

Equipment for adulticiding varies depending on application. ULV products can be applied either by truck-mounted equipment or from fixed-wing or rotary-wing aircraft. Thermal fogs can be applied by hand-held units or truck-mounted equipment. Barrier applications are typically applied with hydraulic sprayers (compression sprayers, knapsack sprayers and line power sprayers), motorized portable mist sprayers and truck mounted mistblowers.

Some mosquito control programs do not go beyond adulticiding. This may be acceptable for the control of single-brooded mosquitoes in mountainous areas where the mosquito problem is generally short, and breeding sites are scattered woodland pools where larviciding is not feasible.

Larvicides

Mosquito control programs are more productive and less costly when the source of the mosquito problem can be found and the immature mosquitoes

are killed before adults can emerge. Larviciding is less controversial than the use of adulticides, although the use of larvicides generates concerns about its effects on nontargeted animals. Commonly used larvicides are classified as chemical, monomolecular films, petroleum distillates, growth regulators and microbial.

Chemical. The most popular chemical for larval control is Temephos (commonly known as Abate®). It is the only organophosphate used for this purpose. It is an important insecticide resistance management product and is often used along with other treatment programs. When used according to label instructions, this product does not pose unreasonable risks to humans. [64] Because it may pose some risks to nontarget aquatic animals, the EPA has restricted its use to areas where less-hazardous products are effective. The chemical is applied in liquid, granule and pellet form.

Figure 6-8. Knapsack sprayers are used by the Southwest Ada County Mosquito Abatement District for spraying breeding sites where larger equipment may not have access.

Monomolecular Films. Monomolecular films are low-toxicity pesticides that spread a thin film on the water surface of the breeding site of mosquitoes. This product makes it difficult for larvae, pupae and emerging adults to attach themselves to the surface of the water, which causes them to drown. Monomolecular films do not pose a risk to humans when used according to label instructions. [64] This product poses minimal risks to the environment.

Petroleum Distillates. Refined oils, much like films, are used to form a coating on top of the water to drown larvae, pupae, and emerging adult mosquitoes. When used according to label instructions, oils do not pose a risk to humans. If misapplied, oils may be toxic to fish and other aquatic organisms.

Growth Regulators. Methoprene is a popular growth regulator which prevents the immature forms of the mosquito from developing into adults. When used according to label instructions, the product poses little risk to humans, wildlife or the environment. [64] Methoprene is applied to mosquito breeding sites as a liquid, impregnated briquets, pellets, or granules.

Microbial. Microbial larvicides are very popular because they are nontoxic to humans and do not pose risks to wildlife, nontarget species, or the environment, when used according to label instructions. [64] Two species of bacteria are used, *Bacillus thuringiensis israelensis* (commonly called Bti) and *Bacillus sphaericus*. The bacteria damages the gut of the mosquito larvae when consumed, causing death. The bacteria are applied as aqueous suspensions, technical powders, granules, briquets, or water soluble pouches.

As with the application of adulticides, equipment used for applying larvicides varies depending on the product. Most larvicides are applied by hydraulic sprayers (compression sprayers, knapsack sprayers, line power sprayers, and sprayers mounted on either fixed-wing or rotary-wing aircraft), motorized backpack mist sprayers, truck mounted mistblowers, granule applicators (simple horn seeders, cyclone spreaders, and blower-type applicators) or by hand for briquets.

Mosquito Fish

The most effective and best known predator of the immature stages of the mosquito is the Western Mosquitofish (*Gambusia affinis*). It is a top minnow, the female being about 2½ inches long and the male about an inch shorter. Because of their fondness for feeding on mosquito immatures, this fish has been exported to virtually all tropical and warm-temperate parts of the world. Cold-resistant strains

have developed and are used in colder climates for mosquito control. [172] *Gambusia affinis* has been called the most widely introduced fish in the world. [142] In recent years, their use has been criticized by some conservation groups and federal and state agencies. [47]

Figure 6-9. Mosquito fish are very effective in controlling mosquito larvae populations (Courtesy of Utah Division of Wildlife Resources).

The female mosquito fish produces live young rather than eggs. There are 6 to 10 young in a brood and there are up to five broods per year. [111] Their food intake is positively correlated to the size of the fish; the fry primarily feed on the first and second instar mosquito larvae and the larger fish feed primarily on third and fourth instars and pupae. [219] The mosquito fish will prey on mosquito larvae in water less than one inch deep.

Mosquito fish have been introduced into Idaho waters on several occasions, although historical accounts of the introductions are limited. [193] Anecdotal information indicates that mosquito fish have been established in Ada County, Elmore County, Owyhee County, Nez Perce County, Bear River drainage, and Snake River above Shoshone Falls. [2, 208] Mosquito fish have been distributed to the public in years past by a local Idaho health agency. [208] These fish have been used by several mosquito abatement districts in the state.

Since mosquito fish are weak swimmers, they are not able to cope with the strong currents of rivers and streams. [142] Where predator fish exist, mosquito fish are reduced and confined to very shallow water and dense clumps of emergent vegetation. [142] In Idaho, mosquito fish are more suitable for survival in slower water courses, such as ditches, standing water of gravel pits, farm ponds, log ponds, wastewater lagoons, retention ponds, ornamental pools and similar bodies of water which are more permanent, moderately deep and where winter conditions are milder. In both Utah and Oregon, mosquito fish overwinter under the ice and sustain themselves in fairly cold water. [142, 172]

In New Jersey, where mosquito fish have been stocked since 1905, the recommended stocking rates are as follows: large bird bath - 10/site, ornamental pond/abandoned swimming pool - 35-100/site (depending on size), retention ponds - 1,000/acre, gravel pits - 2,500/acre (for immediate control) and ditches (1-2 yards wide) - 1/every yard of ditch length. [56] Additional information about using mosquito fish for mosquito control is provided by the American Mosquito Control Association. [126]

In Idaho, there is a great potential for the utilization of mosquito fish as an alternative to traditional mosquito control methods. The distribution of mosquito fish is regulated by the Idaho Department of Fish and Game. At the present time, only mosquito abatement districts can provide these fish to approved sites within their jurisdiction. [162] Information on sources of mosquito fish in Idaho is provided in Chapter 10.

Physical Management and Maintenance

Some mosquito breeding sites are extensive and may require significant improvements to abate the problem. However, such efforts usually not only eliminate mosquito breeding, but also enhance land usability and productivity. The following physical management methods are beneficial in all respects: providing drainage; filling depressions and low areas; grading; ditch improvements; and improving irrigation water delivery, application, drainage, and return-flow systems. Such improvements may require technical assistance, as well as permits. The agencies mentioned in Chapter 10 should be consulted.

Habitat maintenance is important for reducing mosquito breeding in existing water delivery, application and drainage systems. Leaks in irrigation canals, laterals and ditches need to be repaired and vegetation controlled. Drainage ditches need to be properly maintained. Routine vegetation control is necessary for farm ponds, retention ponds and other water impoundments. In these water systems and others (wetlands near populated areas, municipal infrastructure such as street gutters, catchbasins

and drains, etc.) for which management is not performed or is impractical, the areas need to be identified as potential breeding sites and monitored for mosquito breeding.

Insecticide Resistance

Reliance on the continued use of specific insecticides for mosquito control promotes insecticide resistance. In 1992, on a worldwide basis, it was reported that ninety-five important mosquito species had developed resistance to one or more insecticides. [216] Within the past four decades, four Idaho mosquito species became resistant to insecticides in other areas of the United States. [190] Resistance is established when a mosquito population withstands an insecticide which was generally lethal to earlier generations. As resistance is established and toxicant levels are increased, control efforts must be altered at some point to control the resistant mosquito and prevent environmental damage.

Integrated Pest Management

Integrated Pest Management (IPM) has developed primarily according to agricultural models established many decades ago. [74] With regard to mosquito control, IPM can be defined as an effective program which utilizes a combination of information and techniques including the following: mosquito identification (what mosquito is causing the problem), surveillance (to determine the source of the mosquitoes), monitoring (to determine timing of control efforts or no control at all), action thresholds (to determine when control measures will be taken), control techniques (source reduction, personal protection, biological control, use of insecticides, etc.), continuing education (for those associated with mosquito control and the general public) and recordkeeping (to determine the effectiveness of the program and for reporting purposes).

An effective mosquito control program is not without the proper utilization of IPM practices; all techniques should be used. The effectiveness of an IPM program is measured by the effectiveness of each control technique used to reduce the number of mosquitoes and their bites. [74] Implementing control practices with restrictive-use insecticides (as identified in this chapter) without the utilization of surveillance and monitoring techniques (identified in Chapter 8) is antiquated.

7

Mosquito Abatement Districts

The National Centers for Disease Control and Prevention (CDC) recognizes that properly funded and operated mosquito abatement districts are the most effective and economical way to control mosquitoes. [19]

In 1959, the Idaho State Legislature passed the Idaho Mosquito Abatement Act. This legislation provided for the formation of mosquito abatement districts at the local level. Twelve districts have been established in this state since the establishment of the Act.

Forming a Mosquito Abatement District

The first step in the formation of a mosquito abatement district is to determine the interest of the property owners in the affected area in forming a district. The size of the area can be as small as four square miles (or even smaller) or the size of an entire county. Formation is generally initiated by a group of concerned and motivated persons in the area who make personal contacts with other property owners. This group may call a public meeting at a local school or grange hall to discuss the mosquito problem. It is at such meetings that governmental, public health, and private agencies may be invited to discuss the situation and possible solutions to the mosquito problem.

Figure 7-1. Making personal contacts and providing useful information about forming a mosquito abatement district enhances the success of the effort.

Legal Initiative Procedure

If there is a sincere interest in forming a mosquito abatement district, certain legal procedures must be followed in order to initiate the districting process. This may take two years, so an immediate mosquito problem cannot be solved by this effort. Nevertheless, positive steps to forming a district is rewarding and will be an asset to the citizens within the district.

The following procedures must be followed (the county office should be able to provide some guidance) (Idaho Code Section 39-2802):

- A legal petition requesting the formation of a mosquito abatement district must be generated and signed by ten percent of the resident property owners (of the proposed district) that voted in the last general election;
- The petition must define the boundaries of the proposed district and assessed tax valuation of the property therein;
- The county commissioners shall publish the petition according to law;
- If no protests are received after thirty days, an election must be held at the next date specified by Idaho Code Section 34-106 (the petitioners shall bear the expense of holding the election);
- If there are written protests, the county commissioners must hold a public hearing within thirty days after receipt of the written protests;
- The election must be held after proper notice; and
- The majority of the votes will establish the district.

Figure 7-2. Citizens in the Canyon County Mosquito Abatement District appreciate white pickups with the above logo; mosquito control has never been so good.

Selection of Officers

In accordance with Idaho Code Section 39-2803, a five-member board of trustees is appointed by the county commissioners to oversee the operation of the mosquito abatement district. The trustees must be individuals who are property owners and registered voters from within the mosquito abatement district boundary.

The trustees shall serve without compensation, but will be reimbursed for necessary expenses associated with the performance of their official duties.

The trustees will have the assistance of two *ex officio* members, the county health officer and county agent. In addition, the directors of the following agencies shall be considered *ex officio* members of the board and may be called upon for their advice and assistance in the handling of abatement problems: agriculture, fish and game, lands, transportation, water resources and health and welfare.

Method of Financing

A mosquito abatement district does not come without cost. "How much does it cost?" is the most common question regarding the formation of a district. Excluding start-up costs, [108] a "barebones" mosquito control program can cost less than a can of bug spray per year for property with an assessed value of $100,000. [194] However, a more effective and lasting mosquito control program will cost a little more. Would quality mosquito control be worth three cans of bug spray per year?

The district is financed by all property owners within the boundaries of the mosquito abatement district. Upon approval of the budget and work plan, the board of county commissioners must levy a tax upon taxable property within the district to finance the mosquito control program (Idaho Code Section 39-2805).

All taxes levied are collected in the same manner as other taxes and deposited to the credit of the mosquito abatement district. These funds shall be used for no other purposes. Such funds may be withdrawn from the county treasury upon warrant of the board of trustees of the abatement district for mosquito control activities.

Powers and Duties

The powers and duties of the board of trustees of the mosquito abatement district are as follows (Idaho Code Section 39-2804):

- To appoint a director to direct the activities of the district, in accordance with training and experience necessary to fulfill the duties of the position;
- To appoint such other persons as necessary, determine their duties and compensation, and make rules and regulations pertaining to them;
- To take all necessary and proper steps for the control of mosquitoes and other vermin of public health importance in the district and for these purposes shall have the right to enter upon any and all lands;
- Contract to purchase, hold, dispose of, and acquire by gift real and personal property in the name of the district;
- To exercise the right of eminent domain and for these purposes to condemn any necessary land and/or rights of way in accordance with general law;
- To abate as nuisance, breeding places of mosquitoes and/or other vermin of public health importance within the district or within migrating distance of the district by use of chemicals and/or permanent control measures and in this connection have the right to enter upon any and all lands;
- To work with the lateral ditch water users associations, irrigation, drainage and flood control districts and other cooperating organizations. The board of trustees of the abatement district may supplement funds of cooperating organizations for improvement, repair, maintenance and cleaning of ditches which will temporarily or permanently eliminate mosquito breeding or for other activities which will benefit the district; and
- To sue (and be sued).

Important and Necessary Reporting

In accordance with Idaho Code Section 39-2804(h and i), the board of trustees of the mosquito abatement district shall produce and provide the following reports annually to the board of county commissioners:

- An estimate of funds required for the next year, a plan of the work to be done, and the methods to be employed (no procedure, work or contract for any year of operation shall be done or entered upon until plans and budget have been jointly approved by the board of county commissioners); and
- File annually or by February 1 of the succeeding year with the board of county commissioners, a report setting forth the monies expended during the previous year, methods employed, and work accomplished.

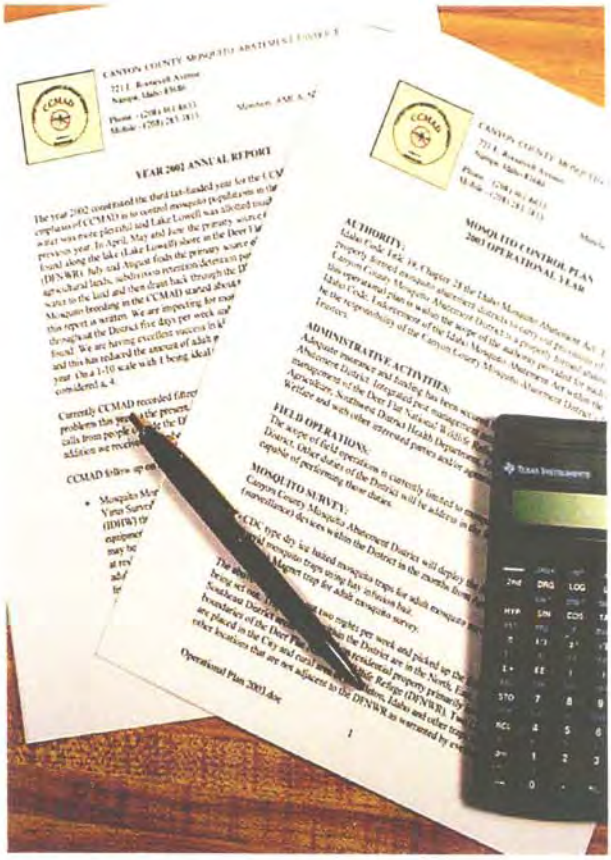


Figure 7-3. At the end of the season, mosquito abatement district work is not finished until the paperwork is done. Depicted are *Year 2002 Annual Report* and *Mosquito Control Plan 2003 Operational Year* of the Canyon County Mosquito Abatement District.

These reports are public record and subject to review by anyone interested in mosquito control activities in the district.

Promoting Effective Mosquito Control

Although the public may only be interested in the reduced exposure to biting mosquitoes, the county commissioners and board of trustees of the mosquito abatement district should focus on an integrated mosquito control with emphasis on source reduction, where practical. Too often, the practice of mosquito control is to put emphasis on adulticiding without regard to the technical aspects of effective control, based on the mosquito species causing the problem and their biology (where they breed, periods of activity, etc.).

Adulticiding for mosquitoes is a necessary element of an integrated mosquito control program. It is important: 1) as an interim measure, to be used until other integrated control methods can be implemented; 2) where mosquito problems occur so infrequently that other control methods are not justified; 3) when adjacent to wildlife areas and public lands where other means of mosquito control are not supported or protected by law; and 4) where the danger of disease demands immediate action. [138, 139]

Training

To promote an effective mosquito control program, the board of county commissioners and the board of trustees should insist on having employees associated with mosquito control properly trained.

Mosquito abatement district directors and managers should have the following knowledge, skills and abilities:

- Knowledge of modern techniques, methods, procedures, principles and practices of all phases of mosquito control;
- Knowledge of mosquito biology and the ability to identify important local species;
- Knowledge of approved chemicals for mosquito control and their proper application;
- Skill in written and oral presentation of reports and presentations;
- Ability to address civic organizations or other public or private groups on mosquitoes and their control;
- Ability to plan, direct and supervise, coordinate, organize and inspect mosquito control plans, programs and activities and evaluate their effectiveness;
- Ability to plan and coordinate mosquito surveillance and evaluation programs and analyze data collected; and
- Ability to prepare, develop and present long-range mosquito control plans. [1]

Mosquito control technicians or operators should have the following knowledge, skills and abilities (or have the willingness to be trained in the respective areas):

- Basic knowledge of important local mosquitoes and their biology;
- Knowledge of mosquito control pesticides and proper application;
- Skill in the operation and an understanding of spray and mechanical systems and equipment;
- Ability to make field inspections and interpret findings;
- Ability to keep accurate records pertaining to work performed; and
- Ability to work effectively with trained supervisors and the general public. [98, 129, 202]

Public Education

The success of any mosquito abatement program is the continued support of the property owners within the district. It is important to keep property owners informed of the various activities of the district through occasional press releases (particularly ULV spray schedules), providing prompt response to service requests, and maintaining a "call before spraying" list. In addition, consideration should be given to distributing information sheets and brochures, presenting educational programs in schools and for citizen and civic groups, placing displays in business windows and having an occasional exhibit in the county fair.

Enabling Legislation

For the interest of the reader or individuals interested in forming a mosquito abatement district, the Act is provided as follows in its entirety:

CHAPTER 28
MOSQUITO ABATEMENT DISTRICTS

39-2801. Authorization to form abatement districts. – There may be formed, under the provisions of this act, districts for the abatement of mosquitoes and/or other vermin of public health importance, in any area of the state from territory of one or more counties, one or more cities or towns, or any combination or portion thereof.

39-2802. Procedures for formation of abatement districts. – Upon presentation to the board of county commissioners of a petition requesting the formation of an abatement district, which is signed by qualified resident property owners of the territory of the proposed abatement district, equal to not less than ten percent (10%) of the resident property owners that voted in the last general election, the commissioners shall publish such petition when the following conditions are met: the petition must define the boundaries of the proposed district and assessed tax valuation of the property therein. When the above conditions have been met the county commissioners shall publish the petition, and if after thirty (30) days no protests are received, an election must be held at the next date specified in section 34-106, Idaho Code. The petitioners shall bear the expense of holding the election. If there are written protests, the county commissioners must hold a public hearing within thirty (30) days after receipt of the written protests and after the hearing hold an election. Notice of the time and place of such election shall be published at least once not less than twelve (12) days prior to the election and a second time not less than five (5) days prior to the election in at least one (1) newspaper having general circulation in the proposed abatement district. Only qualified electors who own land within the district, or the proposed district, and are residents of the county in which the district, or a portion thereof, is located, or are spouses of such landowners residing in such county, may vote on the formation of the district. A majority of the votes cast will establish the district.

39-2803. Selection of officials of abatement districts. – A five (5) member board of trustees shall be appointed from within the area of the proposed abatement district to govern the abatement district. The trustees appointed shall at the first meeting of each year elect a president, secretary and treasurer to serve during the ensuing year. The officers of the board shall be bonded to the extent of five hundred dollars ($500) to five thousand dollars ($5,000) each as set by the county commissioners. The members of the board shall be appointed by the county commissioners of the county which they are to represent. When two (2) or more counties or portions thereof comprise an abatement district, the selection of trustees will be made by mutual agreement of the county commissioners concerned. Each trustee shall be a resident property owner and a registered voter. Trustees shall be appointed for four (4) years on staggered appointments. To initiate the board two (2) members are appointed for two (2) years, one (1) for three (3) years and two (2) for four (4) years. Subsequent appointments shall be for four (4) years. Trustees shall serve without compensation but will be reimbursed for necessary expenses involved with the performance of their official duties. The county health officer and the county agent shall be ex officio members of the board. Whenever two (2) or more counties or portions thereof are included in the district, the health officer and county agent for each county shall be ex officio members of the board. The [directors or] heads of the following state departments or their designated representatives shall be considered ex officio members of the board and may be called upon for their advice and assistance in the handling of abatement problems affecting their direct interests: agriculture, fish and game, lands, transportation, water resources and health and welfare.

39-2804. Powers and duties of abatement districts. – The abatement district board of trustees is authorized: a. To appoint a director to direct the activities of the district, in accordance with training and experience necessary to fulfill the duties of the position. b. To appoint such other persons as necessary, determine their duties and compensation, and make rules and regulations respecting them. c. To take all necessary and proper steps for the control of mosquitoes and other vermin of public health importance in the district and for these purposes shall have the right to enter upon any and all lands. d. To sue and be sued. e. Contract to purchase, hold, dispose of, and acquire by gift real and personal property in the name of the district. To exercise the right of eminent domain and for these purposes to condemn any necessary land and/or rights of way in accordance with general law. f. To abate as nuisance breeding places of mosquitoes and/or other vermin of public health importance within the district or within migrating distance of the district by use of chemicals and/or permanent control measures and in this connection have the right to enter upon any and all lands. g. To work with the lateral ditch water users associations, irrigation, drainage and flood control districts and other cooperating organizations. The board of trustees of the abatement district may supplement funds of cooperating organizations for improvement, repair, maintenance and cleaning of ditches which will temporarily or permanently eliminate mosquito breeding or for other activities which will benefit the district. h. To file annually with the board of county commissioners for their approval an estimate of funds required for the next year, a plan of the work to be done, and methods to be employed. No procedure, work or contract for any year of operation shall be done or entered upon until plans and budget have been jointly approved by the board of county commissioners. i. To file, annually or by February 1 of the succeeding year, with the board of county commissioners a report setting forth the moneys expended during the previous year, methods employed, and work accomplishments.

39-2805. Method of financing abatement districts. – The board of county commissioners must levy upon taxable property within the district a tax at a rate not

greater than sufficient to raise the amount determined by the board of trustees as approved by the board of county commissioners, as necessary for the operation of the district for the ensuing year. In no event shall such tax exceed one tenth percent (.1%) of the market value for assessment purposes on all taxable property within the district. All taxes thus levied shall be collected in the same manner as other taxes and deposited to the credit of the abatement district and shall be used for no other purposes. Such funds may be withdrawn from the county treasury and upon warrant of the board of trustees of the abatement district, signed by the president of the board and countersigned by its secretary, for the activities of the abatement district.

39-2806. Annexation to abatement districts. – Contiguous territories may be annexed to organized mosquito abatement districts upon petition of a majority of the legal voters in the territory seeking annexation and of the owners of more than half, by assessed value, of the taxable property in such territory, or by written request for annexation of a designated area, submitted to the trustees of the existing mosquito abatement district and signed by all members of the board of county commissioners in which county the territory seeking annexation is located. Upon receiving this petition or written request, the trustees of the existing mosquito abatement district must submit the question of annexation to the legal voters of the district at an election held subject to the provisions of section 34-106, Idaho Code.

39-2807. Consolidation of abatement districts. – Two (2) or more contiguous districts may be consolidated. Any district board of trustees may seek consolidation by adoption of a resolution by a majority vote of its members. Consolidation is accomplished by a majority vote of the members of each of the boards of trustees involved in the consolidation. The consolidated districts may enter into arrangements for pooling funds and joint use of personnel, equipment, and supplies. The activities conducted under joint arrangement shall be considered as if conducted directly by the board having jurisdiction over the area concerned. The board of county commissioners must be given written notice of consolidation.

39-2808. Existing rights preserved. – It is the purpose of this act to provide additional and cumulative remedies to prevent, abate and control the spread of mosquitoes and/or other vermin affecting the public health, safety and welfare of the people of the state of Idaho. Nothing herein contained shall be construed to abridge or alter rights of action or remedies in equity or under the common law or statutory law, criminal or civil, nor shall any provision of this act, or an act done by virtue thereof, be construed as estopping the state or any municipality or person in the exercise of their rights of equity or under the common law or statutory law to suppress or abate nuisances.

39-2809. Short title. – This act may be cited as the Idaho Mosquito Abatement Act.

39-2810. Withdrawal. – Any portion of a mosquito abatement district which will not be reasonably benefited by remaining within such district may be withdrawn as in this section provided. Upon receiving a petition signed by fifty (50) or more landowners within the portion desired to be withdrawn from any mosquito abatement district, or by a majority of such landowners, if there are less than one hundred (100) landowners within the portion sought to be withdrawn, requesting the withdrawal of such portion from the district on the ground that such portion will not be reasonably benefited by remaining in said district, the board of county commissioners shall fix a time for hearing on such petition and for hearing protests to the continuance of the remaining territory as a mosquito abatement district. The hearing shall not be less than ten (10) days nor more than thirty (30) days after the receipt thereof. The board shall, at least one (1) week prior to the time so fixed, publish notice of such hearing by one (1) publication in a newspaper of general circulation in the district, which the board deems most likely to give notice to the inhabitants thereof, of the proposed withdrawal.

39-2811. Hearing of petition for withdrawal. – Any person interested may appear at the hearing and object to the withdrawal of the portion from the district, or may object to the continuance of the remaining territory as a mosquito abatement district. The board of county commissioners shall consider all objections and shall pass upon the same, and if it finds that portion of the district sought to be withdrawn will not be reasonably benefited by remaining within the district, and the territory not sought to be withdrawn will be reasonably benefited by continuing as a mosquito abatement district, it shall grant the petition and enter an order thereon upon its records. In the event the board finds the district will not be reasonably benefited by continuing as a mosquito abatement district, it shall enter an order upon its records completely dissolving and terminating the previously existing mosquito abatement district. Upon the withdrawal of any territory from a mosquito abatement district, as in this section provided, all property acquired for the district shall remain vested in the county and be used for the purposes of the district. Upon complete dissolution of a mosquito abatement district as herein provided, all property acquired for the district shall remain vested in the county and be used for any general purpose of the county.

Idaho Mosquito Abatement Districts

The following ten active mosquito abatement districts have been formed in accordance with Title 39, Chapter 28, Idaho Code:

- Battleground Mosquito Abatement District
  Scott Johnson, Secretary/Treasurer
  Star Route
  Mackay, ID 83251

  Description: Formed about 1985. Located in Custer

County, the district is approximately 142 square miles in size and includes the communities of Dickey and Chilly and the surrounding Thousand Springs Valley above Mackay Reservoir and west up Trail Creek Road.

- Bear River Mosquito Abatement District
  Ron Peterson, Manager
  327 Jefferson Street
  Montpelier, ID 83254
  Phone: 208-847-0545

  Description: Formed in the early 60s. Located in Bear Lake County, the district is approximately 180 square miles in size and includes Montpelier, Dingle, Pegram and adjacent areas, excluding the Bear Lake National Wildlife Refuge.

- Canyon County Mosquito Abatement District
  Brian Benner, Director
  721 E. Roosevelt Avenue
  Nampa, ID 83686
  Phone: 208-461-8633 or 208-871-1860

  Description: Formed in 1997. The district is 21 square miles in size and includes the southern portion of Nampa and westward to the border of Lake Lowell, including portions of Deer Flat National Wildlife Refuge. Problem mosquitoes include *Aedes vexans* (Inland Floodwater Mosquito), *Ochlerotatus dorsalis* (Salt Marsh Mosquito), and *Culex tarsalis* (Western Encephalitis Mosquito).

- Fairfield Mosquito Abatement District
  Cathy Miller, Manager
  P.O. Box 1
  Fairfield, ID 83327
  Phone: 208-764-3202

  Description: Formed in 1996. Located in the Camas Prairie of Camas County, the district is 4 square miles in size and includes the city of Fairfield and the surrounding vicinity.

- Gem County Mosquito Abatement District
  Quinn Nuffer, Manager
  526 West 3rd Street
  Emmett, ID 83617
  Phone: 208-365-5628

  Description: Formed in 1959. Located in Emmett Valley, the district is 65 square miles in size and includes Emmett, Letha and adjacent areas of the valley south of the Payette River, and the eastern portion of the bench to Black Canyon Dam.

- Jefferson County Mosquito Abatement District
  Reed Williams, Manager
  167 South Third West
  Rigby, ID 83442
  Phone: 208-745-8424 or 208-538-7778

  Description: Formed in 1982. The district is 67 square miles in size and includes Ririe and the adjacent areas primarily between Highway 20, Snake River and the county line to the south.

- Mackay Mosquito Abatement District
  Jack Anderson, Secretary
  410 E. Custer Street
  Mackay, ID 83251
  Phone: 208-588-2438

  Description: Formed about 1988. Located in Custer County, the district is approximately 108 square miles in size and includes Mackay, Leslie, Darlington and adjacent areas below the Mackay Reservoir.

- Madison County Mosquito Abatement District
  Wendell Roth, Manager
  750 North 1500 West
  Rexburg, ID 83440
  Phone: 208-356-3102

  Description: Formed about 1966. The district includes the entire county, 472 square miles.

- Roberts Mosquito Abatement District
  Tom Buxton, Chairman
  2898 East 800 North
  Roberts, ID 83444
  Phone: 208-228-6851

  Description: Formed in 1989. Located in Jefferson County, the district is approximately 30 square miles in size and includes Roberts and surrounding vicinity.

- Southwest Ada County Mosquito Abatement District
  Jack Bennett, Director
  2290 South Liberty
  Boise, ID 83709
  Phone: 208-362-1440

  Description: Formed in 1973. Located in the western portion of Ada County, the district is 480 square miles in size and includes the western edge of Boise and the cities of Eagle, Star, Meridian and Kuna and surrounding areas. Problem mosquitoes include *Ochlerotatus nigromaculis* (Irrigated Pasture Mosquito), *Culex tarsalis* (Western Encephalitis Mosquito) and *Culex pipiens* (Northern House Mosquito).

8

Surveillance, Collection and Preservation Methods

An essential component of an organized mosquito control program is knowing the mosquitoes that are creating problems for the community. All effective control efforts are based on that knowledge, the mosquito's biology, and the population dynamics of the species .[76, 170] To satisfy these requirements, this chapter covers surveillance, collection techniques and preservation methods.

Surveillance

Surveillance, or monitoring, is essential for initiating and sustaining any type of organized community mosquito control program. Without it, control efforts will never be completely efficient and effective. The three types of surveys include the initial survey, operational surveys (monitoring) and arbovirus disease surveillance. [59, 170]

Initial Survey

The purpose of the initial survey is to obtain certain basic information, called baseline data, that must be available for planning, operational and evaluation purposes. This information includes: 1) knowledge about the mosquitoes causing the problem, 2) sources of their breeding, 3) densities, and 4) anticipated flight or impact range.

Mosquito species identification should be the first order of business of a mosquito control program. To properly manage mosquito abatement activities, problem mosquitos need to be identified. Chapter 9 provides for the identification of the most important Idaho mosquitoes.

Figure 8-1. Mosquito identification being conducted at the Canyon County Mosquito Abatement District.

Breeding source determination requires a knowledge of the preferred breeding sites of the mosquito species creating the problem, and physically searching the area for such sites. This activity is labor intensive. However, important information concerning potential breeding site locations can be obtained by reviewing maps and aerial photographs prior to field visits. Field data collected at breeding sites may include type of source, size, environmental characteristics (sunlight exposure, plant growth, permanency, etc.), ownership, and other relevant information.

Population densities of both immature and adult females will provide information about the extent of the problem. Immature collection reports generally include the number of dips with the dipper and the average number of larvae and pupae per dip. Adult female field collection reports generally include the number of landings per minute.

Flight or impact range will determine the extent to which the mosquito may create a problem; this is particularly important with *Aedes* and *Ochlerotatus* mosquitoes. Larval and adult control efforts will be based on this information, even when breeding sites are outside the district boundaries.

Initial survey data is most often obtained at the beginning of starting a new mosquito abatement district, or if not at the beginning, initiated shortly thereafter by necessity. It will take one to three years (depending on the size of the district) to complete the initial survey. Thereafter, additional information will be added to the database as it becomes available. Failure to complete the initial survey may contribute to a less than satisfactory outcome during the formative years of the program, force reliance on controversial adulticiding, and result in a loss of public support.

Maps and Records

The initial survey information is of little lasting value without recording the information. This is generally done with a maps and records system. The type of maps and records management system used can be very basic to systems that are out of this world -- literally. The only limitation is the amount of money budgeted for this purpose.

A very basic mapping system that works well for populated areas in Idaho is the use of county and/or topographical maps. For the most part, Idaho is laid out in "townships" consisting of 36 square miles, and each square mile is called a "section." Most roads in the populated areas of the state are on section lines. Therefore, a mapping system utilizing sections as the smallest mapping unit for survey purposes works well (or the sections can be divided into quarter units). In larger communities, a certain number of city blocks may be utilized in a mapping unit. A simple records system may be a three-ring binder with preprinted forms for data entry. There should be a centrally located master copy and field copies as needed.

In this day and age of high technology, mapping and records management systems may consist of computer generated maps using geographic information system technologies (GIS), digital photographs, satellite imagery and global positioning systems (GPS). Custom software programs provide the generation of information such as breeding site locations, inspection results, land owner information, mosquito population data, historical information, local weather data, control operations data and reports, and more.

Regardless of the type of system used, record-keeping data should be consistent both in method and content. Standardized forms promote accuracy in the transcription and interpretation of data.

Operational Surveys (Site Monitoring)

During the initial survey, every known breeding site, whether a catchbasin, retention pond or several acres of flooded lowlands, should be mapped and recorded in a database system (either manual or computer based).

Breeding sites should be monitored at weekly or biweekly intervals (depending on the mosquito species breeding at the sites; some mosquito species complete their aquatic stage faster than others) to determine breeding status. Through the monitoring process, decisions can be made for determining the necessity of control activities, type, timing, or no control at all. Depending on the site monitoring history, recommendations may be made to seek permanent abatement of the site.

Arbovirus Disease Surveillance

The purpose of arthropod-borne virus (arbovirus) disease surveillance is to determine the status of a disease in the local animal population in order to

predict the likelihood of a human disease outbreak. [59]

For the most part, Idaho's interest in arbovirus disease surveillance has been limited to the Idaho Department of Agriculture notifying the Idaho Department of Health and Welfare of increased numbers of equine arbovirus cases. [53, 65] With the exception of occasional blood tests of large domestic animals, aggressive arbovirus surveillance has not been done until the West Nile virus became a threat to Idaho in 2002, and funding was made available.

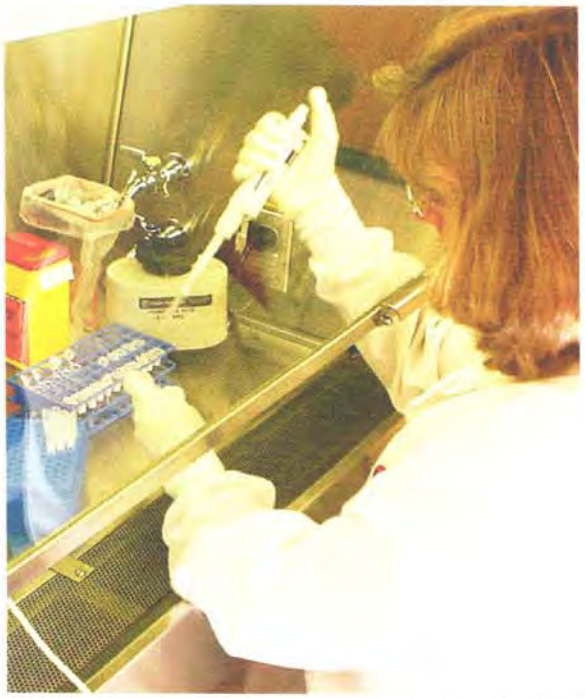


Figure 8-2. Mosquitoes being tested for West Nile virus at the Idaho State Bureau of Laboratories.

The utilization of equine cases as a surveillance tool may become less reliable over time as more and more horses receive vaccinations. [119] Surveillance would be more effective with the use of sentinel flocks and trapped mosquitoes in conjunction with known equine cases. Testing dead birds is also effective for detecting West Nile virus. Finding the West Nile virus in equines, sentinel chickens and dead birds have typically preceded human cases. [114]

Collection Techniques

Collection techniques that satisfy the three surveillance purposes mentioned above include the collection of immature mosquitoes, adult mosquitoes (primarily females), blood samples from sentinel flocks, swabs and/or biological samples from dead birds, horses and humans.

Immature Mosquito Collections

The primary collection tool used to collect mosquito larvae and pupae is a white enamel or plastic dipper approximately four inches in diameter, with handles of varying lengths. Other tools and equipment consists of rubber boots, an assortment of sampling containers or whirl-pak bags for live specimens, a wide-mouth pipette or turkey baster (looks like a giant pipette), vials of cellosolve (2-ethoxyethanol) (or 70% ethyl alcohol) for preserving specimens, siphons made of vinyl tubing (for collecting larvae from hard-to-reach sites and treeholes), a flashlight (for looking in dark potential breeding sites), and a supply of labels and preprinted forms, as necessary.

Figure 8-3. Utilizing the traditional dipper is an effective method for checking for mosquito breeding or collecting specimens.

Larvae and pupae are collected with care. They are very sensitive to vibrations and shadows, and

will dive when disturbed. The immatures can be scooped up with the dipper, or when found in cans and items too small for the dipper, they can be collected directly from the container with the pipette or baster.

Larvae collected for rearing purposes should be poured into a sampling container or whirl-pak bag. Additional water and debris from the site should be added and the container should be properly labeled. Specimens from other sites should not be added to the same container, another container should be used. Containers with specimens should not be stored in a place where the water will receive direct sunlight and become overheated.

There are several different types of rearing mechanisms that can be used. A simple multiple rearing unit used by Santa Clara County Health Department (see Figure 8-5) consisted of shelves on which standardized containers of water holding the larvae and pupae were placed, while screen-topped mailing cartons were placed on the shelf above. The bottoms of the mailing cartons and the shelves have similar-sized holes. The emerging adults fly through the hole into the mailing cartons and are captured. Construction information and instructions for this unit are available. [58]

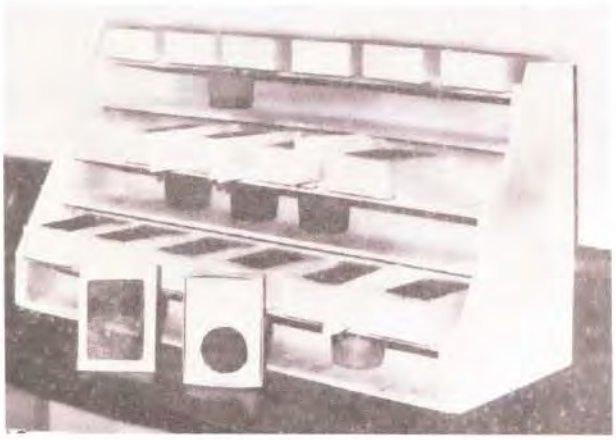


Figure 8-5. This multiple rearing unit is useful in obtaining adult mosquitoes from larvae (Reproduced by permission of Dean Jamieson).

Larvae to be preserved in the field should be processed in the following manner: 1) remove as much water as possible from the container holding the specimens (pour off first and then use a pipette), 2) add cellosolve to kill and fix the larvae, and 3) label the vial immediately to avoid mixing up specimens. It will be necessary to change the cellosolve upon returning to the shop or office (see preservation section for procedure).

Adult Mosquito Collections

Collection methods for adult mosquitoes include aerial or sweeping nets, mechanical devices using lights, motors and gasses, and structures large enough to hold a horse. Information about these collection methods are as follows:

Insect nets (aerial nets, for catching mosquitoes in flight, and sweeping nets for catching adults resting in grass and other vegetation) are useful in determining the abundance of mosquitoes in an area. Captured mosquitoes can be individually removed from the net with an aspirator or killed in a container with a layer of plaster of paris saturated with ethyl acetate or another killing agent.

Figure 8-6. A sweeping net is a useful tool for sampling adult mosquitoes resting in vegetation. Mosquitoes are removed from the net with an aspirator.

Daytime resting sites are locations where the adult female rests during the day. Good sites include under bridges, in large culverts, dense

vegetation close to the ground, and other sheltered places where it is dark, cool and humid.

Landing rate collections may be accomplished by one individual, or even better with two, with each person taking turns as the "bait." When female mosquitoes land on the "bait person" to feed, they are collected using a collection tube or aspirator. Count the mosquitoes collected in 10 or 15 minute intervals. Large domestic animals, such as a horse or cow, may also be used. It is advisable to blindfold the animal and be careful when collecting from the rear end. The population of female mosquitoes attempting to feed are often too numerous to count by this method.

Figure 8-7. Demonstrating the use of an aspirator for conducting a landing rate collection.

Animal bait traps can be a small trapping device containing a rodent or a bird, or a much larger structure containing a larger animal. Cone or V-shaped entrances allow the female mosquitoes to enter and not escape. Animals are generally placed inside the trap in the evening and removed the next morning.

Carbon dioxide traps utilize a trap about the size of a 12x18-inch plastic pipe with inverted cones at each end. Dry ice wrapped in several layers of newspaper is used as an attractant.

New Jersey mosquito light traps are popular for monitoring mosquito populations. They require 110 volt house current and have an "electric eye" or timer to turn the trap on shortly before dusk and off at dawn. Traps should be located in the same place each year to show trends. They are usually checked once a week. Mosquitoes attracted to the light are drawn into a killing jar by a fan. Dichlorvois-impregnated strips (Vapona™) are commonly used as a killing agent. New Jersey light traps have some minor drawbacks. They require connections to house current, they collect some non-target insects, and not all mosquito species are attracted to them. In years past, this type of trap was useful in monitoring populations of the five most important mosquito species in Ada County. [13]

Figure 8-8. A New Jersey mosquito light trap is a useful monitoring tool.

CDC miniature light traps are used primarily for collecting live mosquitoes for virus assays. The operation concept is similar to the New Jersey trap, but it operates on a battery. CO_2 is used as an attractant, and the killing jar is replaced with a collection bag. These traps collect a greater number and variety of mosquitoes. Traps are checked after each night's operation. CDC light traps are being used in Idaho for collecting mosquitoes for arbovirus testing.

CDC gravid traps are unique in that they collect *Culex* females searching for a place to oviposit (lay eggs). [182] Therefore, the trap catches female mosquitoes that have ingested at least one blood meal. It is a very important trap used to collect mosquitoes for virus isolation. Its construction consists of a container of organic rich water beneath a fan and a collection bag. The trap operates on batteries.

It is important to remember that adverse climatic conditions, as well as the brightness of the moon, affect the mosquito's attraction to the traps. Trap collections of *Culex tarsalis* may decrease during the brightest phase of the moon cycle. On the other hand, trap collections of *Aedes* and *Ochlerotatus* species may actually increase. [52]

Figure 8-9. CDC miniature light traps are useful for collecting live mosquitoes for virus assay. Dry ice (used as the carbon dioxide source) is placed in the ammo container on top of the trap).

Other Surveillance Collections

Blood samples from sentinel flocks (usually chickens) have been used for decades to detect arbovirus activity. Utah mosquito abatement agencies have been using sentinel flocks since 1958. [85] Currently, Utah mosquito abatement districts are actively using 21 chicken flocks throughout the state for the detection of Western and St. Louis Encephalitis (WEE, SLE) and West Nile virus (WNV). [86]

Blood is drawn from the chickens every two weeks by pricking the comb with a pin, collecting the blood on filter paper and drying. [86] Laboratory personnel rehydrate the samples for testing. Idaho has not adopted this form of arbovirus testing.

Dead birds are one of the first signs of WNV in an area. [31] Crows and other members of the Corvidae bird family (includes ravens, magpies and jays) are most susceptible to the disease. Most states have adopted some form of dead bird testing. Idaho health districts are coordinating the collection of samples of corvids, and the Idaho Department of Fish and Game is coordinating the collection of samples from birds of prey (raptors such as eagles, hawks, falcons, owls, etc.) [107]

Horses and other equines suspected of having acquired an arbovirus disease are reported to the Idaho Department of Agriculture. [105,107]

Suspected human cases of WNV should be reported by health care providers to the district health department or the Idaho Department of Health and Welfare Office of Epidemiology, and specimens should be submitted to the Idaho State Bureau of Laboratories. [107]

Preservation

The preservation of mosquito specimens has not received it due attention. However, preserving a few adults and larvae has important application to mosquito control.

Most important is the maintenance of a reference collection of local mosquitoes for identification comparisons and staff training purposes. Often mosquito abatement personnel or health department staff are first to recognize new mosquitoes creating problems for the community. If problematic mosquitoes need to be sent to a specialist for positive identification, properly mounted and labeled specimens are preferred. Also, properly mounted mosquitoes become important voucher specimens, which gives credibility to the find. In addition, any public relation presentation may be enhanced by displaying a mosquito collection.

There are several mosquito preservation methods, some of which can be quite involved. In order

to encourage interest in this activity, the procedures included in this section will simplify the process and still provide quality specimens.

Prior to describing the procedures, an important comment is worth noting. Mosquito specimens without collection data are almost worthless. In most incidents, after confirming the identification of the mosquito, the collection data becomes more important than the specimen. The minimum data to include with the mosquito specman will be described below. Additional information may be provided in a log and referenced to the specimen by an accession number.

Figure 8-10. A properly curated mosquito collection aids mosquito control workers in identifying mosquitoes that create community problems.

Preserving Adult Mosquitoes

Adult mosquitoes included in a reference collection should be prepared as soon as possible after killing, or they will become brittle. Adults reared from immatures should not be killed for 12 to 24 hours after emerging so the body can harden; this reduces excessive shrinkage. Use No. 3 size insect pins for pinning. Position paper points cut from card stock (1/8 inch x 3/8 inch) about 3/8 inch from the head of the pin. A pinning block drilled to a depth of 1 1/8 inches simplifies the location of the point on the pin. With the mosquito laying on its left side with its head facing forward, bend the tip of the point, dip it in water soluble "white glue" and apply it to the right side of the mosquito.

With current technology, labels printed on card stock can be easily generated on a computer. Using a 4 pt font size, 140% letter spacing, 0.05 inch line height and 0.1 inch line spacing, six lines of type can be placed on a label 5/16 inch x 10/16 inch in size. Hand-written labels, using a micro pen, also works well. The minimum information recorded on the label should be the state, county, location where the mosquito was collected, date and collector (see Figure 8-11). Pin the label towards the right side so the point with the mosquito will be centered. Labels containing additional information may be placed below the primary label. In addition, a determination label should be provided when the mosquito is identified.

Figure 8-11. Properly pinned and labeled adult mosquito.

Pinned mosquitoes should be kept in a collection box with a soft bottom or in unit trays in a tight box for safekeeping (Figure 8-10). Remember, dried insects are very brittle and can easily be damaged. Do not put anything in the collection box that can move around and destroy the specimens. Keep a tight fitting lid on the collection box when it is not being used. To preclude damage from dermestid beetles, securely pin a piece of a dichlorvois-impregnated strip (Vapona™) in one corner of the box and replace as needed.

Preserving Mosquito Larvae

The procedure for preserving mosquito larvae can may be technical if the larvae are going to be slide mounted. However, the following process will eliminate the multiple steps of dehydration, clearing and infiltration. Permanently preserved or slide mounted mosquito larvae should be placed directly in cellosolve (2-ethoxyethanol) instead of alcohol. This can be done in the following manner: 1) remove as much water as possible from the container holding the larvae (pour off first and then use a pipette); 2) add cellosolve to kill and fix the larvae; 3) after approximately 30 minutes or so (or upon returning to the shop or office), transfer larvae to a vial (1 or 2 dram size) containing fresh cellosolve; 4) prepare a label, using a good grade bond paper and permanent ink to ensure permanency in the cellosolve; 5) add the word "cellosolve" to the label so a technician will know how to process the specimens for more technical work, if necessary; and 6) fill the vial completely with more cellosolve to reduce damage to preserved specimens due to sloshing.

Larvae preserved in cellosolve clear sufficiently for identification purposes and permit direct mounting on microscope slides using Canada balsam. The following process will produce satisfactory slides: 1) Place a drop or two of Canada balsam in the center of a clean slide; 2) remove an individual larvae from the storage vial with a bent-pointed dissecting (teasing) needle and embed it into the balsam, positioning it for dorsal viewing (dipping the point of the dissecting needle in xylene occasionally will aid in working with the specimen); 3) while viewing the specimen under a dissecting scope, carefully partially sever the lower abdomen with a sharp-pointed scalpel or similar instrument so the terminal portion with the siphon and anal segment will turn and lay flat (not a problem if the terminal segment is completely severed)(also use xylene when working with the scalpel), this step is not necessary when mounting *Anopheles* specimens; 4) dip a cover slip in xylene, drain and place it on the balsam containing the larva (four pieces of small glass fragments may be added before setting the cover slip to prevent crushing large larvae); 5) allow the slide to dry (a week or longer without a drying oven); and 6) using gummed slide labels, include the same information as provided for adults, with the addition of the name of the mounting media (Canada balsam) on the label (Figure 8-12). Always store slides flat. Keep xylene handy for cleaning up Canada balsam.

Slide mounts of the male terminalia may be prepared using the larval process, although better quality slides can be produced using other procedures, such as those described by Carpenter and LaCasse. [17]

More information about surveillance, collection and preservation of mosquitoes is provided by CDC and the Walter Reed Biosystematics Unit of the Smithsonian Institution. [134, 163]

Figure 8-12. Properly mounted and labeled mosquito larva on a slide.

9

Identification

Of the 51 mosquito species and subspecies currently recognized by Brothers and Darsie [03] as existing in Idaho, less than half are of public health or economic importance. Therefore, in order for this guide to maintain its introductory character, identification is primarily focused on these mosquitoes. Although the other mosquitoes have been included in the keys, they are identified to individual species or group of species in order to simplify the identification process. For more precise identification, the works of Darsie and Ward [50] are recommended.

Key characters for identification were derived from several sources. [50, 76, 153, 169] Basic illustrations were redrawn from Pratt and Barnes [169] and modified to show specific characters used for identification. Therefore, attention should be directed only to those characters. Such characters were checked against actual specimens when possible. Every effort has been made to keep the character terms as simple as possible.

Many of the adult characters can be seen with the unaided eye or with a hand lens. Other characters will require a stereomicroscope. Most larval characters must be viewed with a stereomicroscope or compound microscope.

The identification keys are of a dichotomous type; there are only two choices for each couplet. Following the number of each couplet is a number in parentheses. This number is the previous couplet number from which the mosquito was keyed. It enables the identifier using the key to work backwards when an error is made in the identification process. To use the key, compare the adult mosquito or larva with the alternate characters of each couplet. A choice between the two characters must be made depending on which one best fits the mosquito. Following the character that best fits the specimen being identified is a number or species name(s). If it is a number, proceed to the couplet with that number and repeat the process until identification is made. When multiple species are included in the identification, an effort has been made to list them in decreasing order of importance.

Identification Key to Adult Female Mosquitoes of Idaho

Since the following keys are for the identification of female mosquitoes, the specimen must be sexed. This is relatively simple. First, only the females bite. Therefore, any mosquito biting or attempting to bite is female. In addition, the antennae of the female are sparsely haired (Figure 9-1) whereas the antennae of male are bushy. The palpi (singular, palpus) are short in the females (Figures 9-1 and 9-2) of all species except for the females of *Anopheles* mosquitoes, which have long palpi. All males have long palpi which have long hairs and end segments that are angled upwards and slightly clubbed in *Anophe-*

les mosquitoes. The abdomen tip of female mosquitoes is pointed, rounded or blunt, whereas the abdomen tip of male mosquitoes is comprised of a pair of claspers.

Figures 9-1 through 9-4 illustrate the primary characters used in the identification of adult female mosquitoes. These figures, along with the aid of individual character figures, should make identification less difficult.

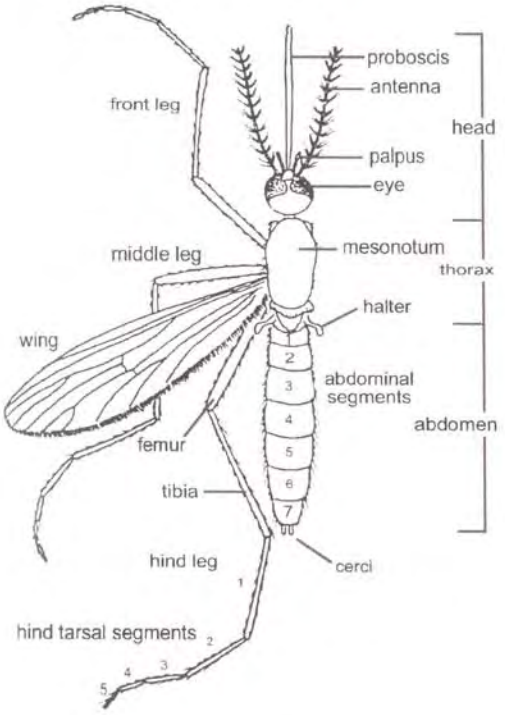


Figure 9-1. Characters used in identifying adult female mosquitoes.

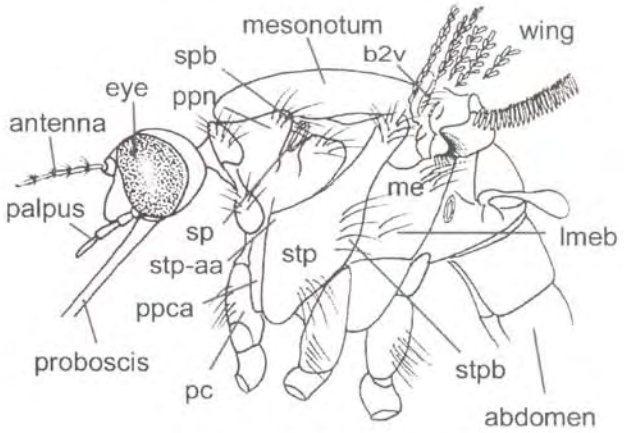


Figure 9-2. Lateral view of thorax of adult female mosquito showing structures and bristles. *b2v*, base of 2nd wing vein; *lmeb*, lower mesepimeral bristles; *me*, mesepimeron; *pc*, procoxa; *ppca*, postprocoxal area; *ppn*, postpronotum; *sp*, spiracle; *spb*, spiracular bristles; *stp*, sternopleuron; *stp-aa*,

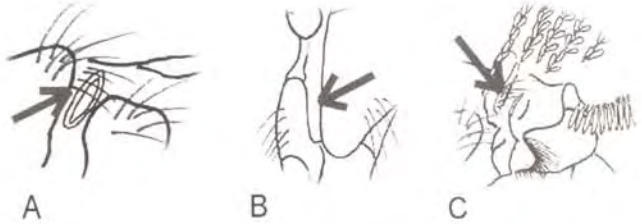


Figure 9-3. Thorax and wing structures which require close examination: **A.** spiracular bristles (*spb*); **B.** postprocoxal area (*ppca*); **C.** base of 2nd wing vein (*b2v*) (underside of wing).

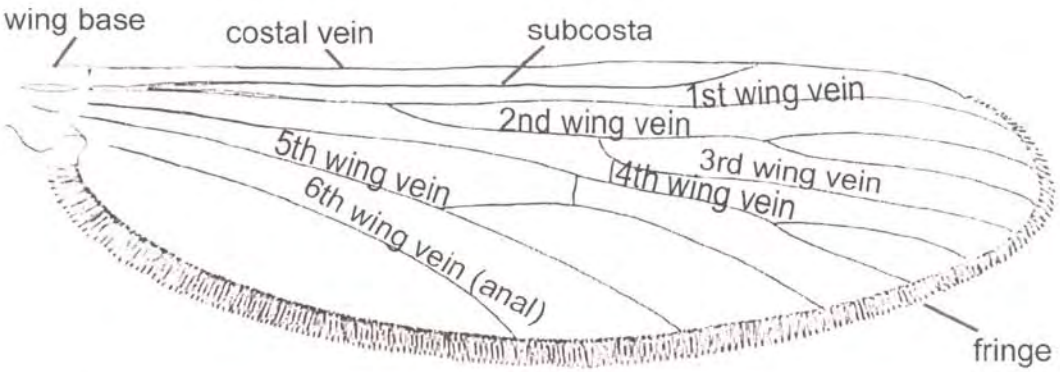


Figure 9-4. Wing characters used in identifying adult female mosquitoes.

The following information will also assist in identification:

- Illustrations are generalized and do not show every minute detail. Some characters are exaggerated slightly in order to enhance their characteristics. Legs are actually longer and narrower than depicted, scales on the legs, wings and body are actually smaller and denser than depicted, body sclerites (hardened parts of the body wall bound by sutures) may not be clearly defined, and there are more bristles and hairs than depicted. The illustrations show the characters and where they are located. Therefore, when viewed under a scope, specimens may appear to be more complicated than the illustrations.
- The older the specimen (in age) the more difficult it will be to identify, primarily due to the loss of scales. Whenever possible, collect a series of mosquitoes from the same species in order to confirm characters. Do not be confused by loose scales; only consider scales that are still attached.
- Spiracular bristles (spb) (Figures 9-2 and 9-3A) are often confused with the bristles on the adjoining postpronotum (ppn) when separating *Culex* and *Culiseta* specimens. As depicted in Figure 9-3A, the spiracular bristles are located on the anterior edge of the spiracle.
- The postprocoxal area (ppca) (Figures 9-2 and 9-3B) is the membranous area between the procoxa (pc) and the sternopleuron (stp).
- Lower mesepimeral bristles (lmeb) (Figure 9-2) are often camouflaged by the overlapping sternopleural bristles (stpb) (Figure 9-2). Look carefully because there may be only one lower mesepimeral bristle.
- "Hairs" on the base of the 2nd wing vein (b2v) (Figures 9-2 and 9-3C) of *Culiseta* are located on the underside of the wing. Descriptions that identify "scales" at the base of the wing refer to the upper surface of the wing.

Key to Genera

1 Palpi almost as long as proboscis . . . . . *Anopheles*
Palpi less than half as long as proboscis (Figure 9-1) 2

2(1) Abdomen tip pointed; cerci conspicuous (Figure 9-5) . . . *Ochlerotatus* and *Aedes*
Abdomen tip rounded or blunt; cerci inconspicuous or concealed (Figure 9-6) 3

3(2) Wing scales broad and intermixed dark and light (Figure 9-7) *Coquillettidia perturbans*
Wing scales narrow and all dark or with a few scattered light scales (Figure 9-8) . 4

4(3) Base of 2nd vein with row of hairs on underside of wing; spiracular bristles present (Figures 9-2, 9-3A&C and 9-9) . *Culiseta*
Base of 2nd vein without a row of hairs on underside of wing; spiracular bristles absent (Figure 9-10) . . . . . *Culex*

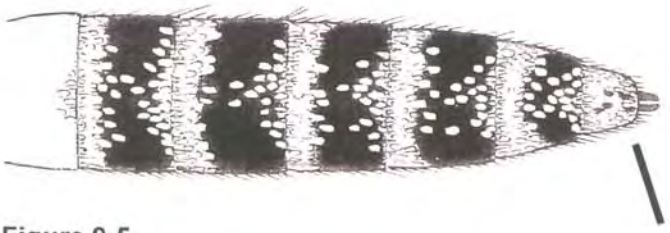


Figure 9-5.

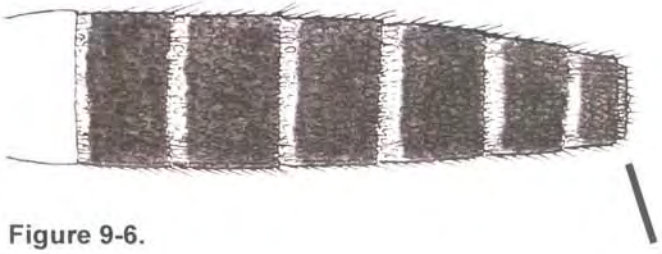


Figure 9-6.

Figure 9-7.

Figure 9-8.

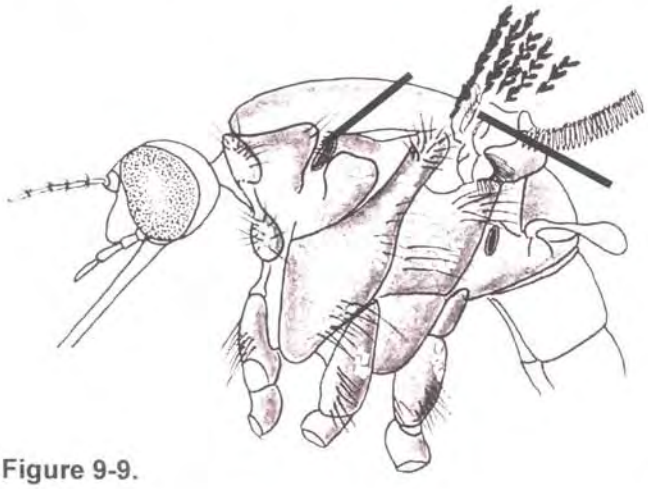


Figure 9-9.

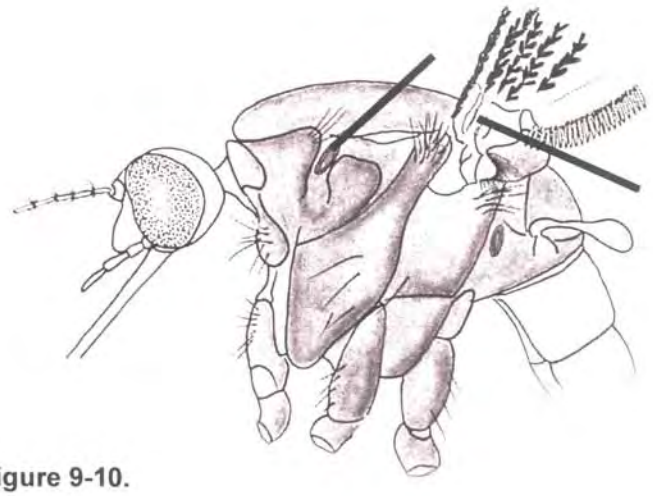


Figure 9-10.

Key to *Anopheles* Females

1 Wings with several patches of light scales (Figure 9-11) . . . . . *An. punctipennis*
Wing scales essentially all dark with possible silvery or copper-colored fringe spot at apex (Figure 9-12) 2

2(1) Wing fringe at apex entirely dark (Figure 9-13) . . . . . *An. freeborni*
Wing fringe at apex silvery or copper-colored (Figure 9-14) . . . . . *An. earlei*

Figure 9-11.

Figure 9-12.

Figure 9-13.

Figure 9-14.

Key to *Ochlerotatus* and *Aedes* Females

1 Hind tarsal segments ringed with light scales (Figure 9-15) 2
Hind tarsal segments not ringed with light scales (Figure 9-16) 11

2(1) Hind tarsal segments with light rings at both ends of some or all segments (Figure 9-17) 3
Hind tarsal segments with light rings at base of segments only (Figure 9-18) 7

3(2) Wing scales dark and light intermixed or with mostly light scales (Figure 9-19) 4
Wing scales uniformly dark or with some light scales at the base of costa (Figure 9-20) 6

4(3) Costal and 6th (anal) veins of wing with dark scales predominating (Figure 9-4, 9-21); abdomen with more dark scales than light scales (Figure 9-22) . . . . *Oc. melanimon*
Costal and 6th (anal) vein usually with light scales predominating (Figure 9-23); abdomen with more light scales than dark scales (Figure 9-24) 5

5(4) 3rd wing vein with dark scales predominating (Figure 9-4, 9-25) . . . . . *Oc. dorsalis*
3rd wing vein with about as many light scales as dark scales (Figure 9-26) . . . . . *Oc. campestris*

6(3) Wings with a patch of light scales at base of costa (Figure 9-4, 9-27) . . *Oc. sierrensis*
Wings without a patch of light scales at base of costa . . . . . *Oc. canadensis*

7(2) Basal rings of hind tarsal segments narrow (Figure 9-1, 9-28); abdominal light bands indented medially (9-29) . . . . *Ae. vexans*
Basal rings of hind tarsal segments broad (Figure 9-30); abdominal scale characteristics vary, but not indented medially (Figure 9-31) 8

8(7) Abdomen entirely covered with light scales (Figure 9-32) . . . . . *Oc. flavescens*
Abdomen with dark and light scales (Figure 9-33) 9

9(8) Abdominal segments with broad basal bands of light scales widening laterally, generally without scattered light scales (Figure 9-34); proboscis dark-scaled . . . . *Oc. increpitus*
Abdomen with or without conspicuous basal bands of light scales, with few to many scattered light scales (Figure 9-35); proboscis with few to many light scales.10

10(9) Abdomen with a distinctive continuous medial longitudinal stripe of light scales (Figure 9-36); proboscis with band or patch of light scales medially (greatly reduced or absent in some specimens) . . . . . *Oc. nigromaculis*
Abdomen without a distinctive continuous medial longitudinal stripe of light scales (Figure 9-37); proboscis dark-scaled with scattered light scales (never with band or patch of light scales medially) . *Oc. fitchii, excrucians, mercurator, eudes*

11(1) Abdominal segments without a basal band of light scales or with basal band significantly interrupted and without scattered light scales (Figure 9-38) . . *Ae. cinereus* (in part), *Oc. hendersoni, trivittatus, decticus, ventrovittis* (in part)
Basal band of light scales on abdominal segments present and not interrupted significantly, often with few to many scattered light scales in some species (Figure 9-39) 12

12(11) Wing scales with an intermix of dark and light scales (light scales may be on alternating veins or scattered)(Figure 9-40) . . . *Oc. spencerii idahoensis, cataphylla, niphadopsis, ventrovittis* (in part)
Wing scales uniformly dark or with a few light scales at the base of costa, subcosta and 1st vein (Figure 9-4, 9-41) 13

13(12) Postprocoxal area with scale patch (Figure 9-2, *ppca*; 9-3B; 9-42) 14
Postprocoxal area without scale patch (Figure 9-43) 15

14(13) Sternopleuron with scales reaching anterior angle or margin (Figures 9-2, *stp-aa; 9-44*) . . . . . *Oc. hexodontus, schizopinax, aboriginis, provocans, pionips, punctor, ventrovittis* (in part).

Sternopleuron with scales not reaching anterior angle or margin (Figure 9-45) . . . . . *Oc. implicatus, impiger*

15(13) Lower mesepimeral bristles present (Figure 9-2, *lmeb*) . . . . . *Oc. communis, pullatus, nevadensis, intrudens.*

Lower mesepimeral bristles absent . . . . . *Oc. sticticus, Ae. cinereus* (in part)

Figure 9-15.

Figure 9-16.

Figure 9-17.

Figure 9-18.

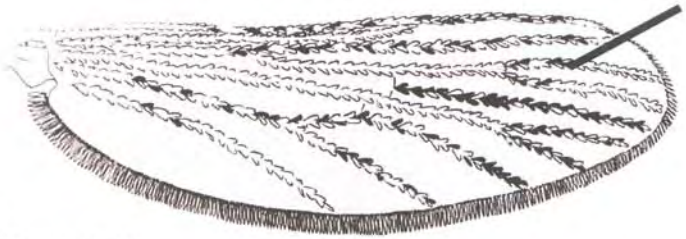
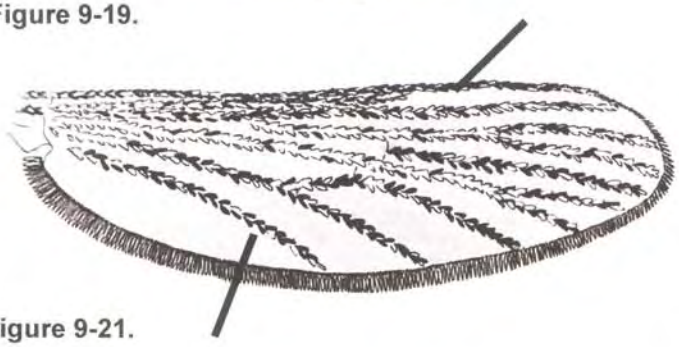


Figure 9-19.

Figure 9-20.



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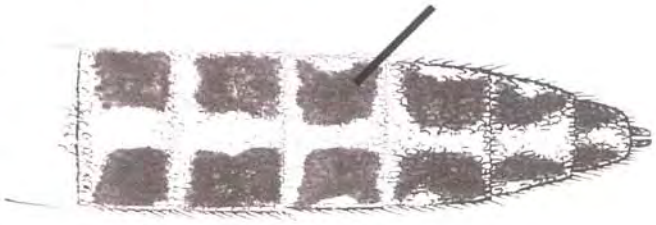

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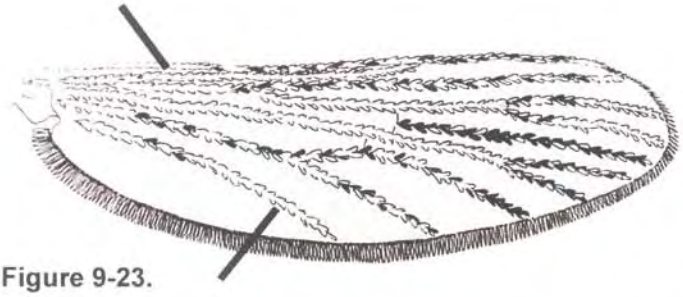

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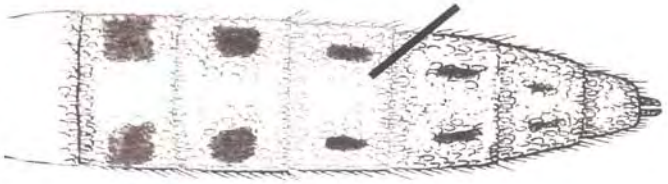

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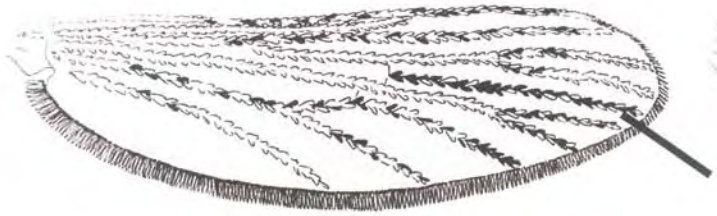


Figure 9-25.

Figure 9-26.

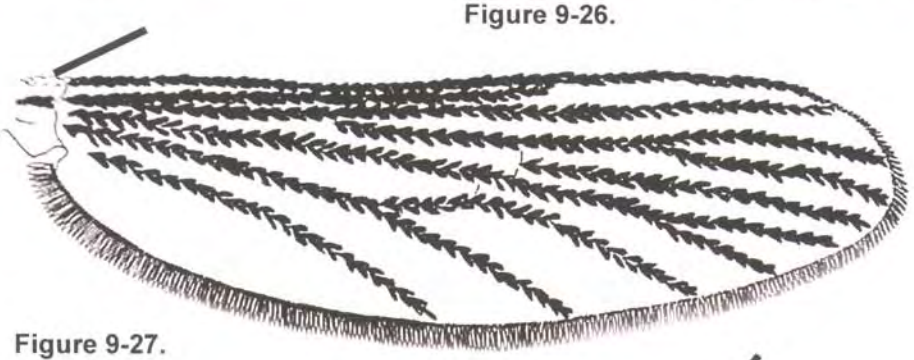


Figure 9-27.

Figure 9-28.

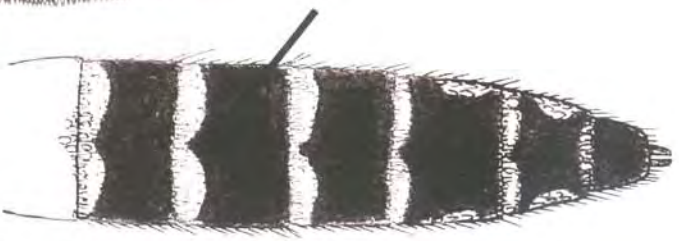


Figure 9-29.

Figure 9-30.

Figure 9-31.

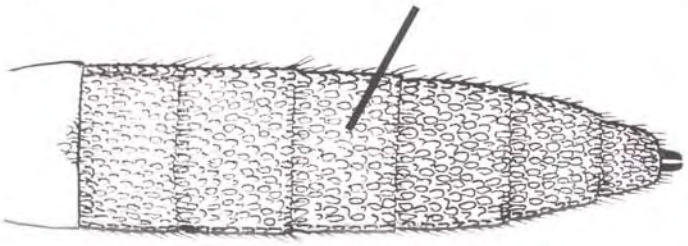
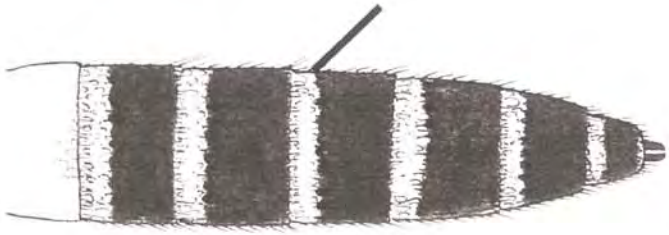


Figure 9-32.

Figure 9-33.



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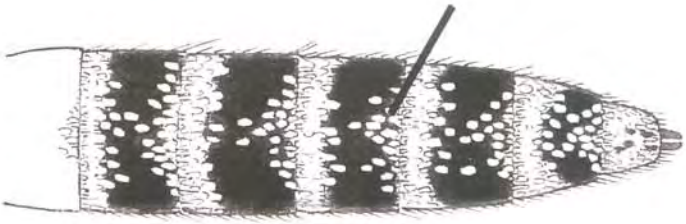

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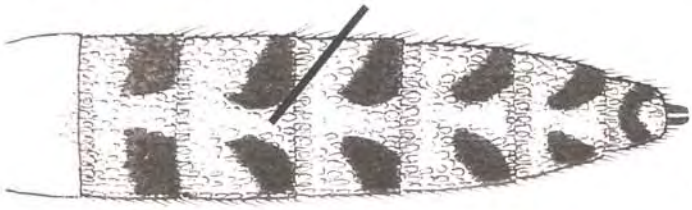

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Figure 9-37.

Figure 9-38.

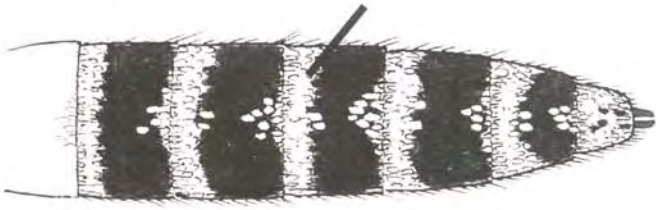


Figure 9-39.

Figure 9-40.

Figure 9-41.

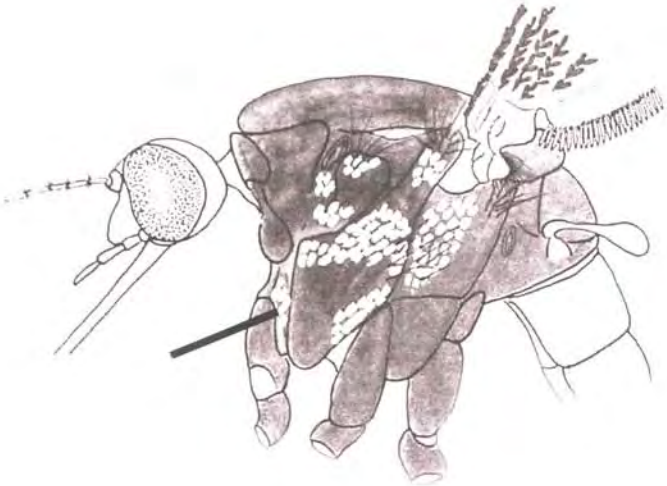


Figure 9-42.

Figure 9-43.

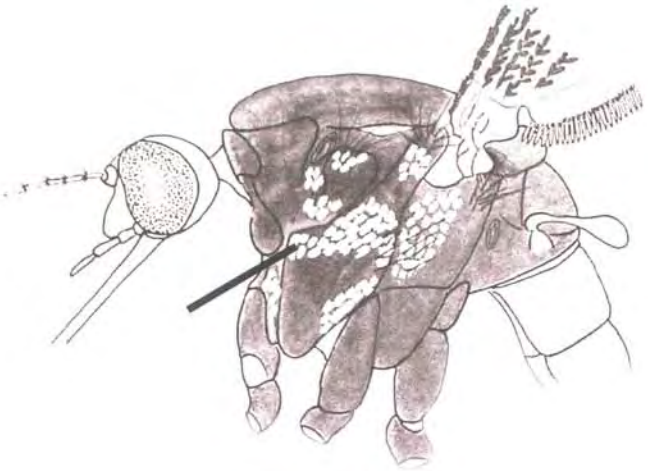


Figure 9-44.

Figure 9-45.

Key to *Culiseta* Females

1 Hind tarsal segments ringed with light scales (very narrow and pale in some species) (Figure 9-46) 2
Hind tarsal segments without rings of light scales (Figure 9-47) 4

2(1) Rings of hind tarsal segments broad (Figure 9-48) . . . . . *Cs. alaskaensis*
Rings of hind tarsal segments narrow (Figure 9-49) 3

3(2) Wings with dense patches of dark scales (Figure 9-50) . . . . . *Cs. incidens*
Wings without dense patches of dark scales (Figure 9-51) . . . . . *Cs. minnesotae* and *morsitans*

4(1) Wings with intermingled dark and light scales on anterior veins (Figure 9-52) . . . . . *Cs. inornata*
Wings with uniform dark scales (Figure 9-53) . . . . . *Cs. impatiens*

Figure 9-46.

Figure 9-47.

Figure 9-48.

Figure 9-49.

Figure 9-50.

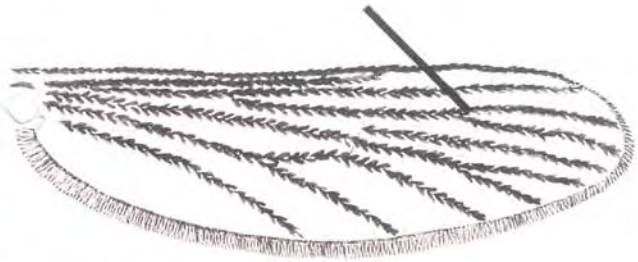


Figure 9-51.

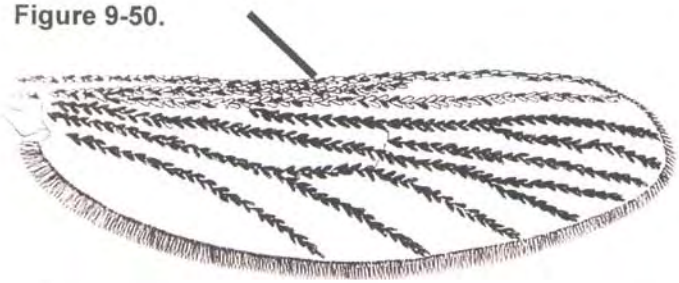


Figure 9-52.

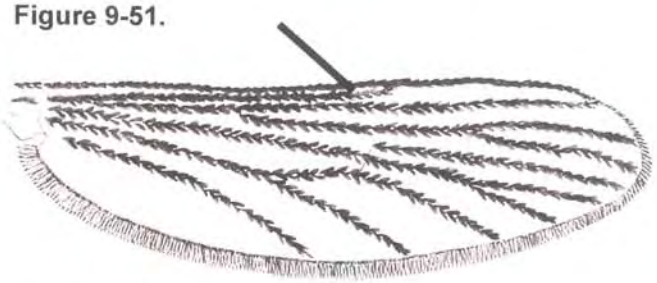


Figure 9-53.

Key to *Culex* Females

1 Hind tarsal segments ringed with broad band of light scales (Figure 9-54) . *Cx. tarsalis*
Hind tarsal segments without rings of light scales or if rings exist, they are very narrow and brownish (Figure 9-55) . . . 2

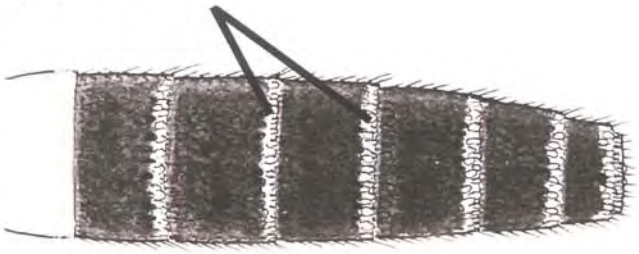
2(1) Abdomen with apical band of light scales (Figure 9-56) . . . *Cx. territans* and *boharti*
Abdomen with basal band of light scales (Figure 9-57) 3

3(2) Mesonotum with integument bright reddish-brown and covered with golden-brown hairlike scales (Figure 9-2) . . . . . *Cx. erythorothorax*
Mesonotum with integument brown to dark brown and covered with narrow curved scales 4

4(3) Abdominal light bands broad and restricted laterally (Figure 9-58) . . . . . *Cx. pipiens*
Abdominal light bands broad to narrow, but not restricted laterally (Figure 9-59) . . . . . *Cx. restuans* and *salinarius*

Figure 9-54.

Figure 9-55.



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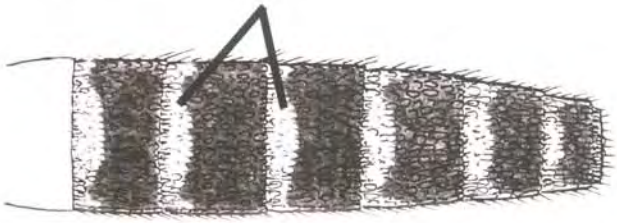
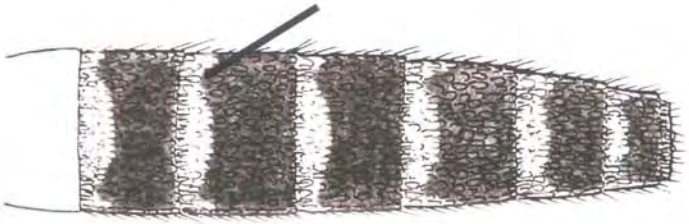


Figure 9-57.



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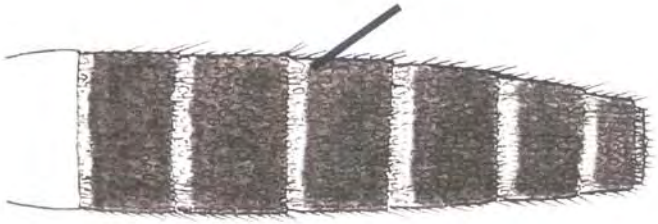


Figure 9-59.

Identification Key to Fourth Instar Mosquito Larvae of Idaho

Figures 9-60 through 9-63 illustrate the primary characters used in the identification of larvae. These figures and individual character figures should simplify identification.

Most live mosquito larvae are difficult to identify. They should be killed with cellosolve (see Chapter 8 section on preservation) and placed in a glass culture or petri dish containing a preservative for examination. Characteristics of the comb scales are best viewed with a compound microscope; the lateral spinules are difficult to observe.

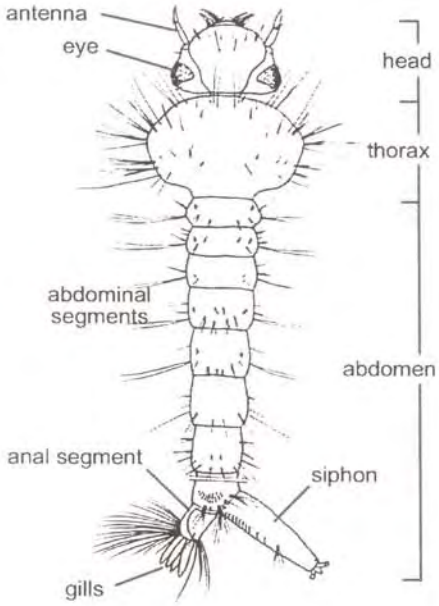


Figure 9-60. Characters used in identifying mosquito larvae.

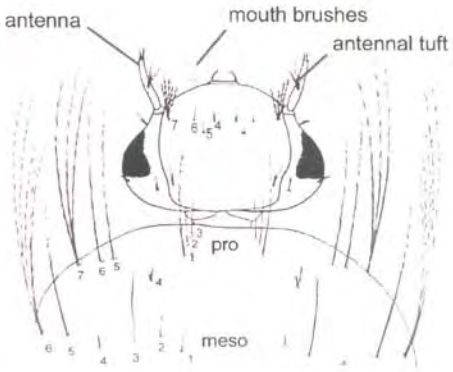


Figure 9-61. Dorsal view of head and thorax of a *Ochlerotatus* larva showing structures and hairs used in identification. *1, 2, 3,* etc., head and thoracic hair numbers; *pro*, prothoracic distribution of hairs; *meso*, mesothoracic distribution of hairs.

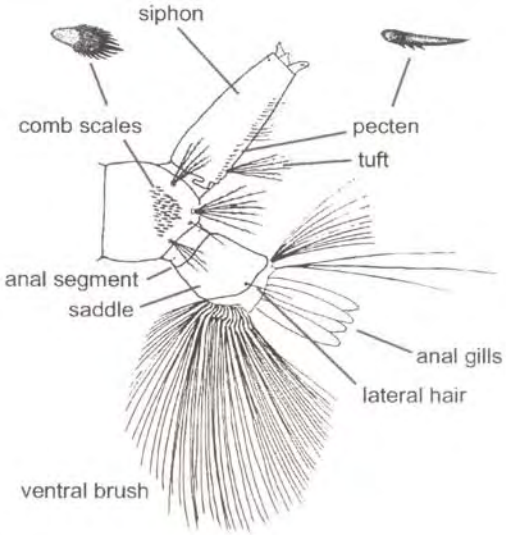


Figure 9-62. Distal portion of mosquito larva's abdomen.

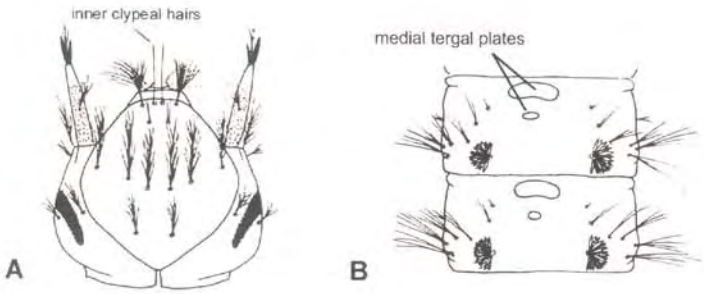


Figure 9-63. Head (*A*) and abdominal segments (*B*) of *Anopheles* larva showing hairs and structures used in identification.

Key to Genera

1 Siphon absent (Figure 9-64) . . *Anopheles*
Siphon present (Figure 9-65) 2

2(1) Siphon reduced to a saw-like pointed tooth for piercing plants (Figure 9-66) . . . . . *Coquillettidia perturbans*
Siphon elongated (Figure 9-67) 3

3(2) Siphon with hair tuft at base (Figures 9-62 and 9-68) . . . . . *Culiseta*
Siphon with tuft within, or distal to, pecten (Figure 9-69) 4

4(3) Siphon with several tufts distal to pecten, some of which may be represented by single hairs (Figure 9-70) . . . . . *Culex*
Siphon with only one principal tuft (usually distal to pecten, or when pecten has detached teeth distally, tuft may be located within detached teeth)[1] (Figure 9-71) . . . . . *Ochlerotatus* and *Aedes*

[1] *Ochlerotatus provocans* has several dorsal and lateral tufts, in addition to the principal tuft.

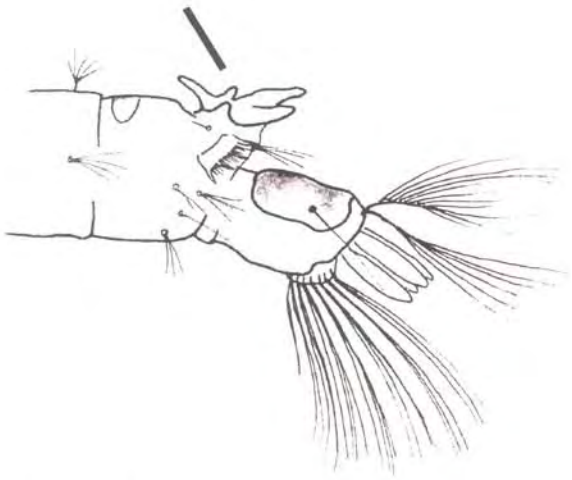
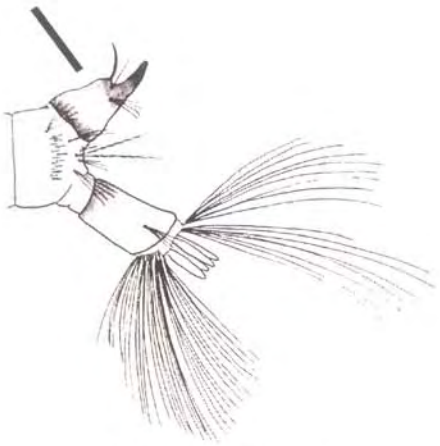


Figure 9-64.

Figure 9-65.



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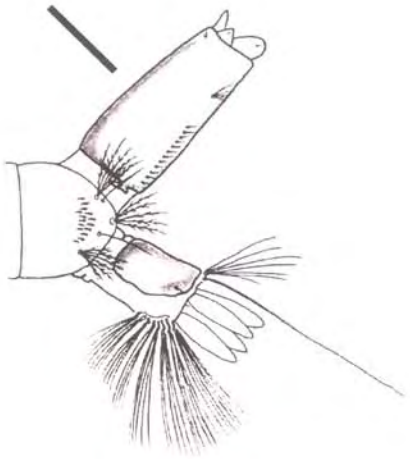

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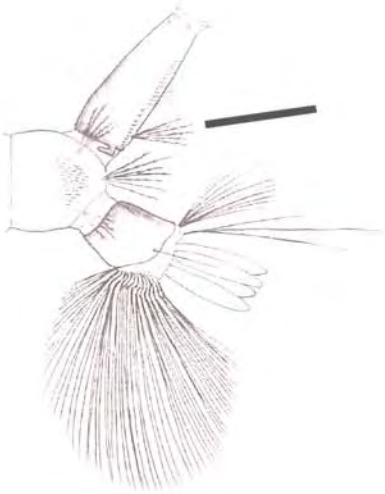

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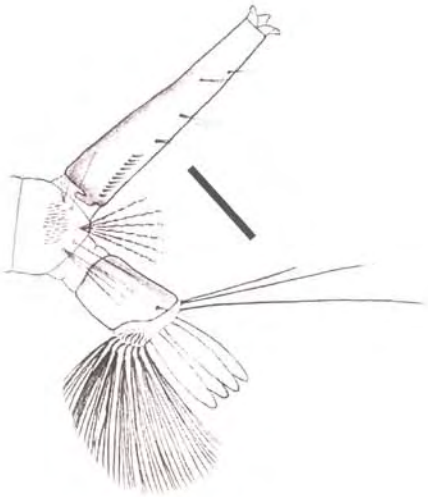

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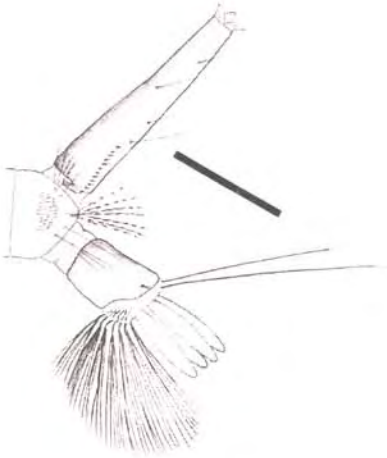

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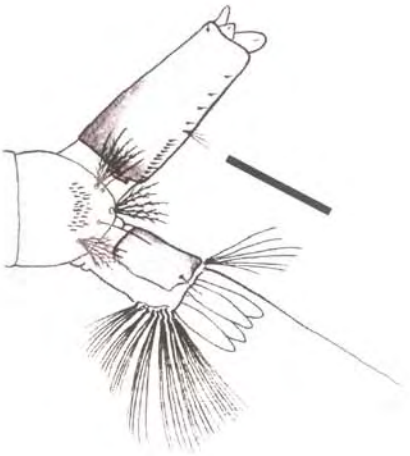


Figure 9-71.

Key to *Anopheles* Larvae

1. Inner clypeal hairs usually forked or branched (Figures 9-63A and 9-72) . . . . . *An. earlei*
   Inner clypeal hairs simple (Figure 9-73) . 2

2(1) Middle abdominal segments with 2 medial tergal plates, 1 large and 1 small (Figures 9-63B and 9-74) . . . . . *An. punctipennis*
   Middle abdominal segments with 4 medial tergal plates, 1 large and 3 small (Figure 9-75) . . . . . *An. freeborni*

Figure 9-72.

Figure 9-73.

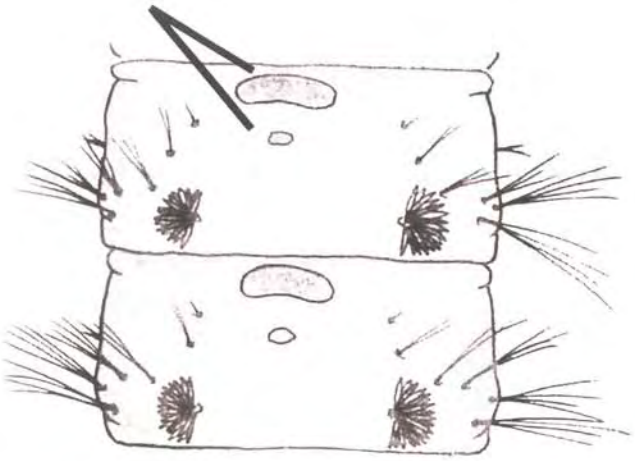


Figure 9-74.

Figure 9-75.

Key to *Ochlerotatus* and *Aedes* Larvae

1 Anal segment completely ringed by saddle (Figures 9-62 and 9-76) . . . . . *Oc. nigromaculis, hexodontus, trivittatus, punctor*
Anal segment not completely ringed by saddle (Figure 9-77) 2

2(1) Pecten with one or more of distal teeth detached (Figures 9-62 and 9-78) 3
Pecten with teeth more or less evenly spaced (Figure 9-79) 8

3(2) Siphon with tuft within pecten (Figure 9-80) . . . . . *Oc. cataphylla, provocans*
Siphon with tuft distal of pecten (Figure 9-81) 4

4(3) Base of head hairs #5-7 nearly in a straight line (Figures 9-61 and 9-82) *Ae. cinereus*
Base of head hair #6 distinctly anterior to hair #5 (Figure 9-83) 5

5(4) Thorax integument covered with miniature spicules (Figure 9-84) . *Oc. s. idahoensis*
Thorax integument smooth (Figure 9-85) 6

6(4) Comb scales 18 or more (Figures 9-62 and 9-86) *Oc. excrucians, campestris* (in part), *flavenscens* (in part)
Comb scales 17 or fewer (Figure 9-87) . . 7

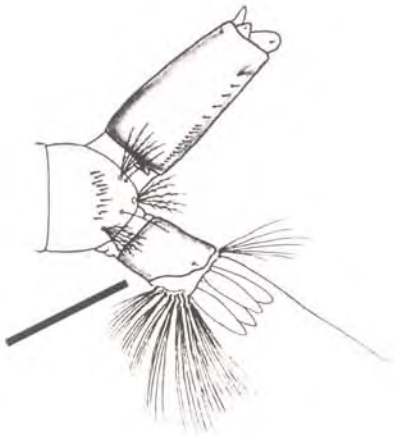
7(6) Head hair #5 with 3 or more branches (Figure 9-88) . . . . . *Ae. vexans, Oc. intrudens, eudes* (in part)
Head hair #5 single or double (Figure 9-89) . . . . . *Oc. niphodophis, ventrovittis, eudes* (in part), *decticus*

8(2) Antennae smooth with antennal tuft consisting of a single hair (treehole mosquitoes) (Figure 9-90) *Oc. serrensis, hendersoni*
Antennae spiculated with antennal tuft with multiple hairs (Figure 9-91) 9

9(8) Comb scales with prominent median spine (Figure 9-92) . . . . . *Oc. sticticus, melanimon* (in part), *fitchi, flavencens* (in part), *nevadensis, mercurator, impiger, schizopinax, aborigenis*
Comb scales with subequal spinules (Figure 9-93) 10

10(9) Head hair #5 with 4 or more branches; head hair #6 with 3 or more branches (Figures 9-61 and 9-94) . . . . . *Oc. c. candensis, pullatus, pionips*
Head hair #5 with 1-3 branches; head hair #6 single or double (Figure 9-95) 11

11(10) Mesothoracic hair #1 equal to length of antenna or longer (Figures 9-61 and 9-96) . . . . . *Oc. dorsalis, campestris* (in part)
Mesothoracic hair #1 shorter than antenna (Figure 9-97) . . . . . *Oc. increpitus, melanimon* (in part), *communis, implicatus*



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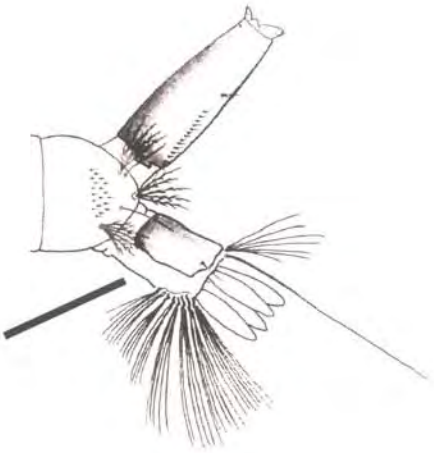

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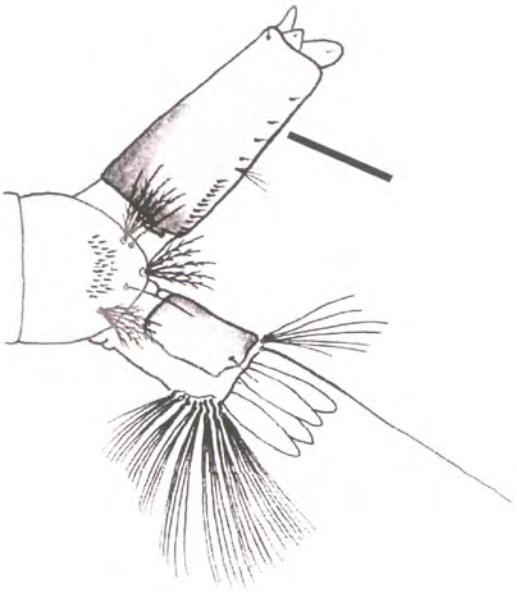

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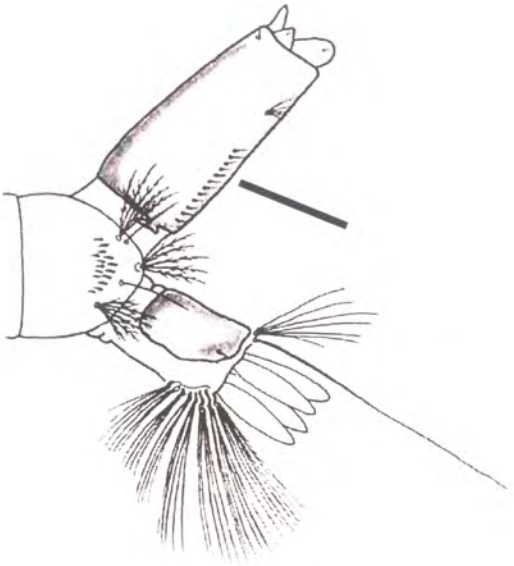

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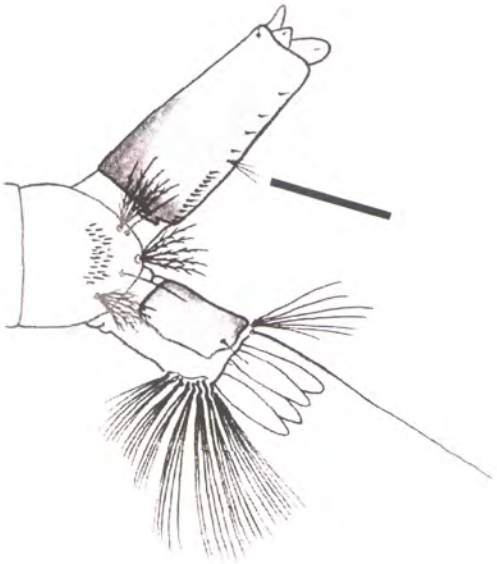

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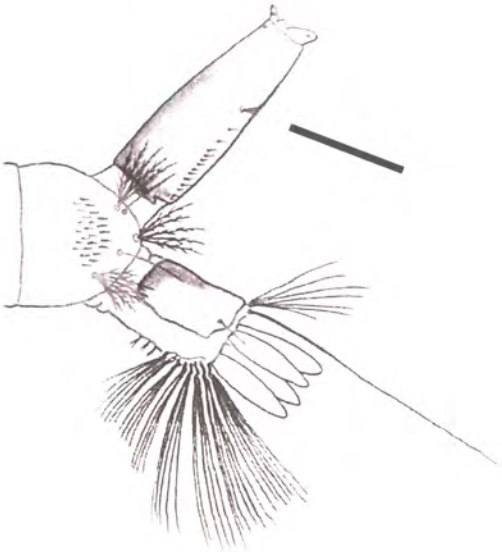
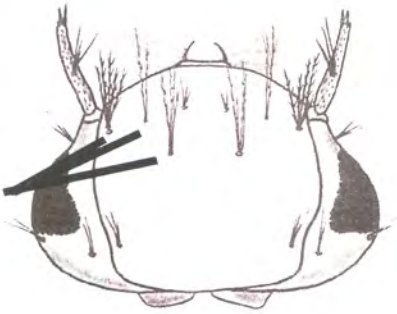


Figure 9-81.

Figure 9-82.



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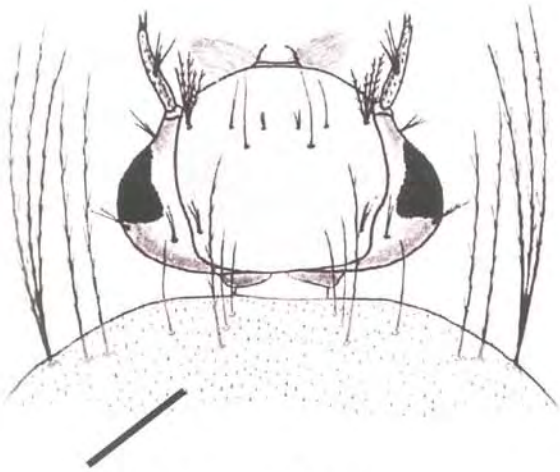

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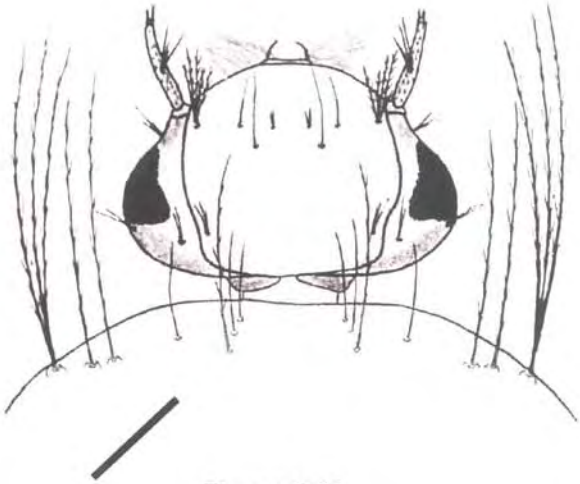

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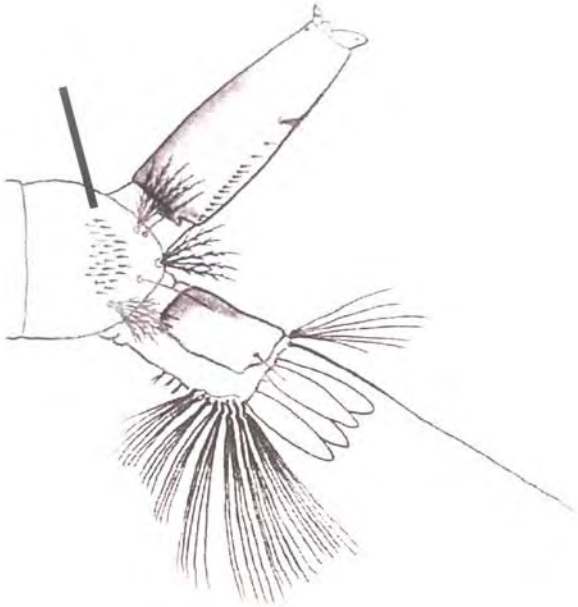

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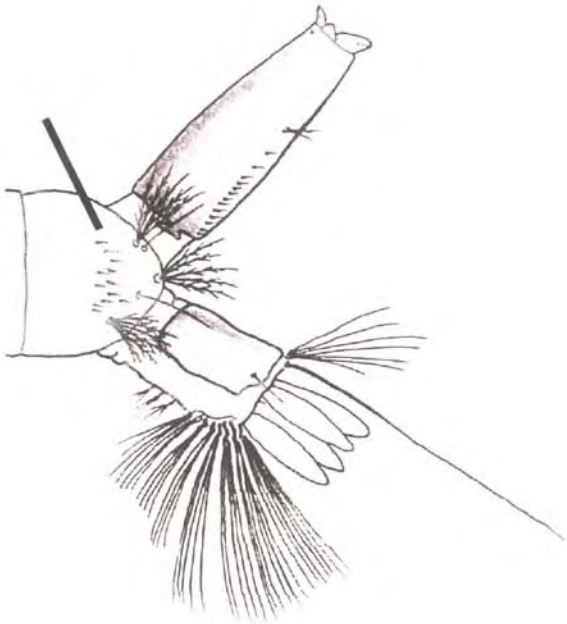

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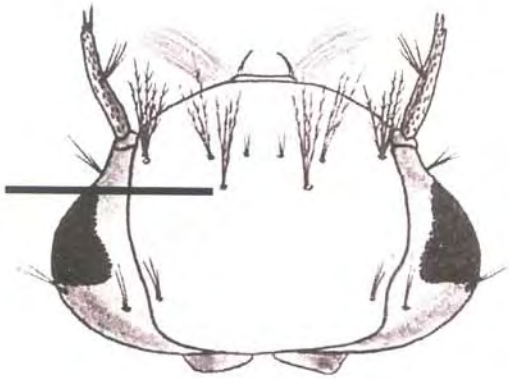

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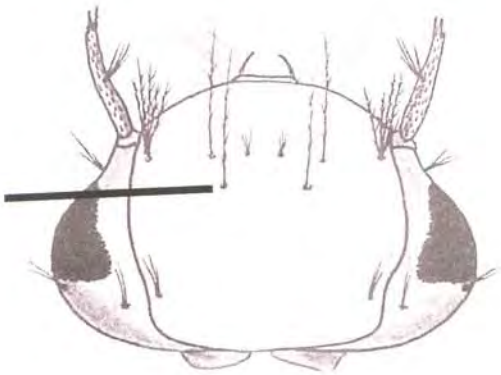

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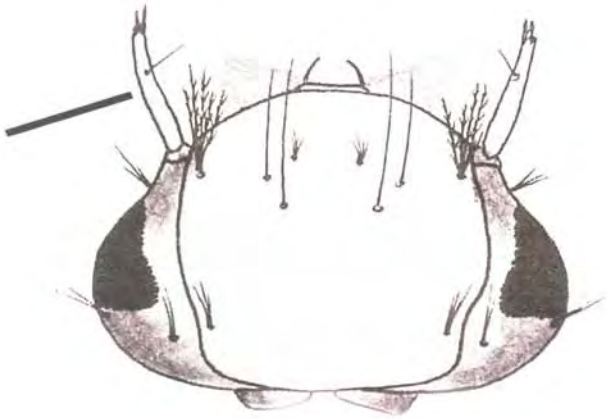

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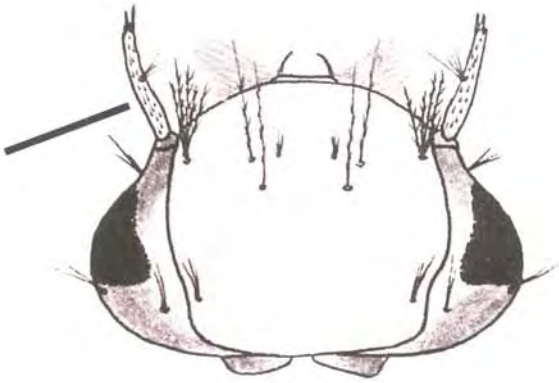

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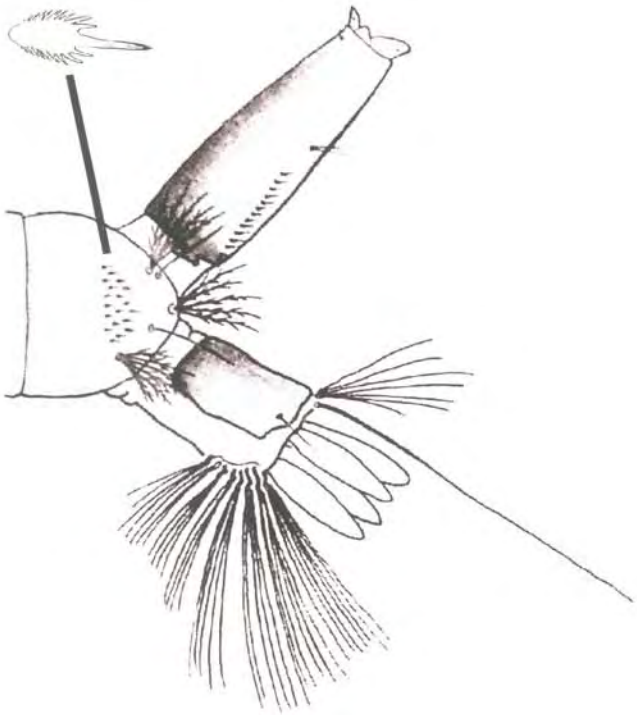

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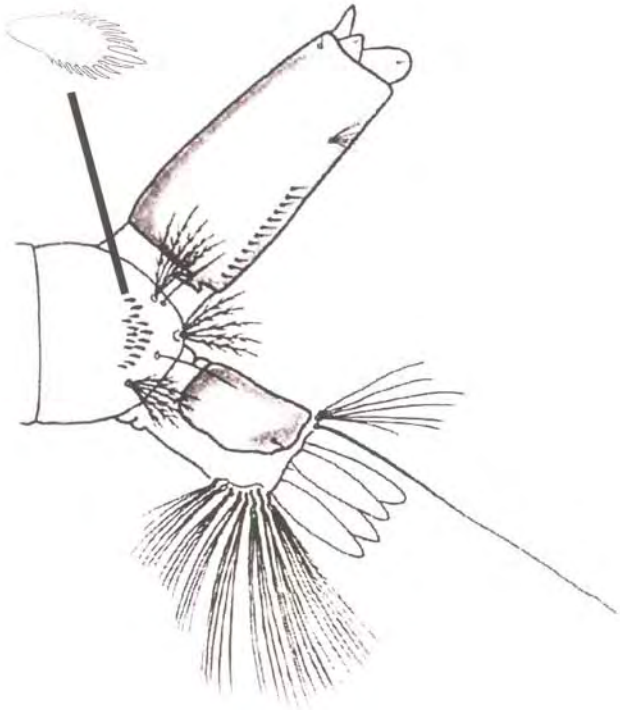

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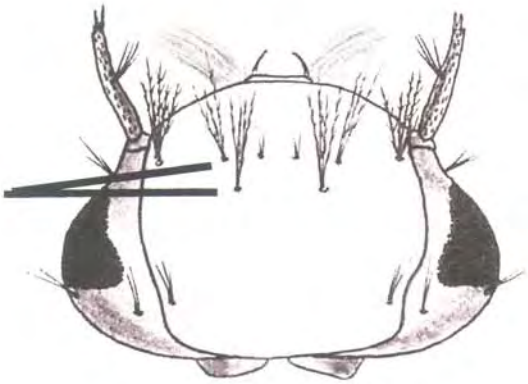

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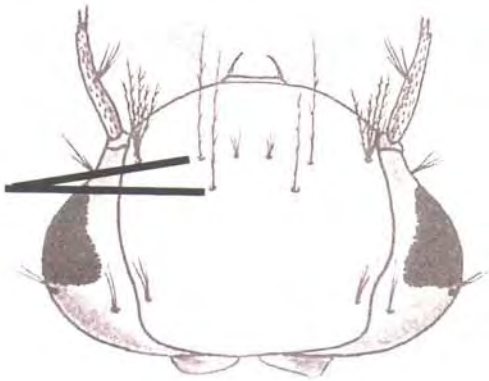

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Figure 9-96.

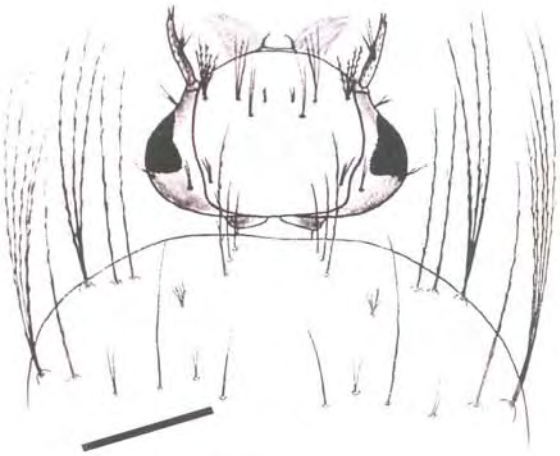


Figure 9-97.

Key to *Culiseta Larvae*

1 Siphon length 6 times or more than its basal diameter; outer pecten teeth not hair-like *Cs. minnesotae, morsitans*

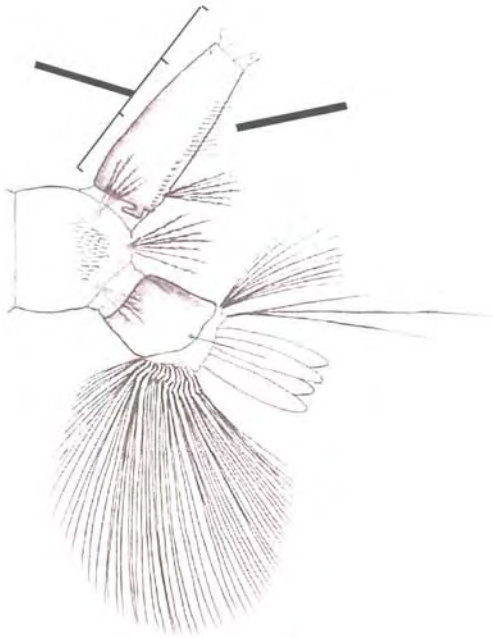
Siphon length less than 4 times its basal diameter; outer pecten teeth hair-like (Figure 9-98) 2

2(1) Lateral hair of anal segment stout and as long or longer than saddle (Figures 9-62 and 9-99) . . . . . *Cs. inornata*

Lateral hair of anal segment fine and shorter than saddle (Figure 9-100) 3

3(2) Anal saddle pierced by two, one or no ventral tufts (Figure 101) . . *Cs. incidens*

Anal saddle pierced by generally three ventral tufts Figure 9-102) . . . . . *Cs. alaskaensis, impatiens*



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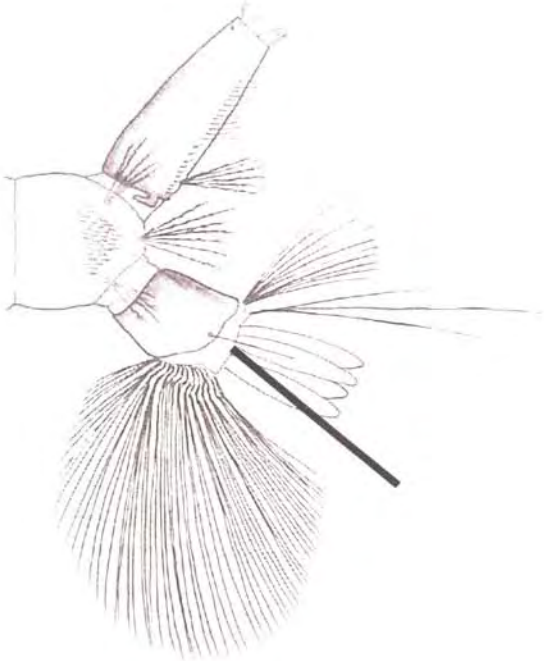

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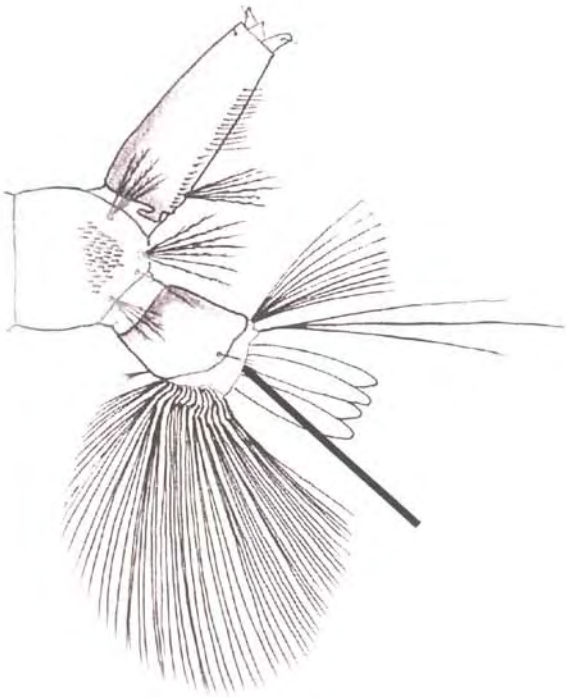

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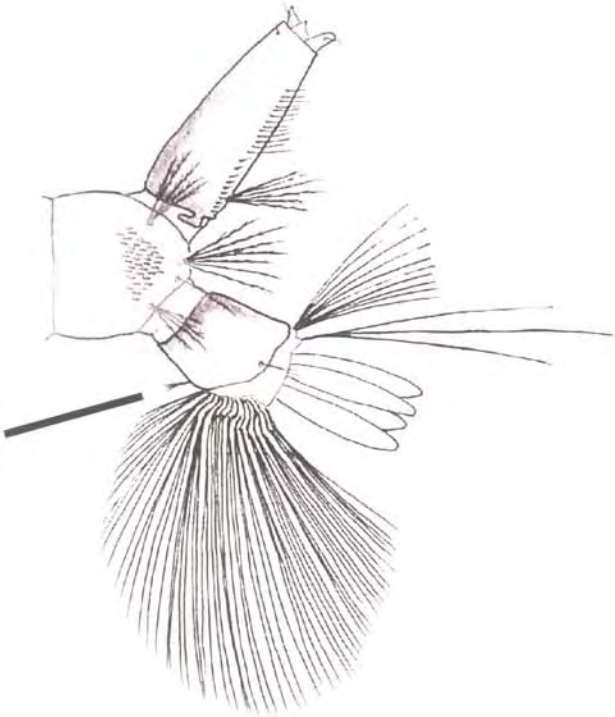

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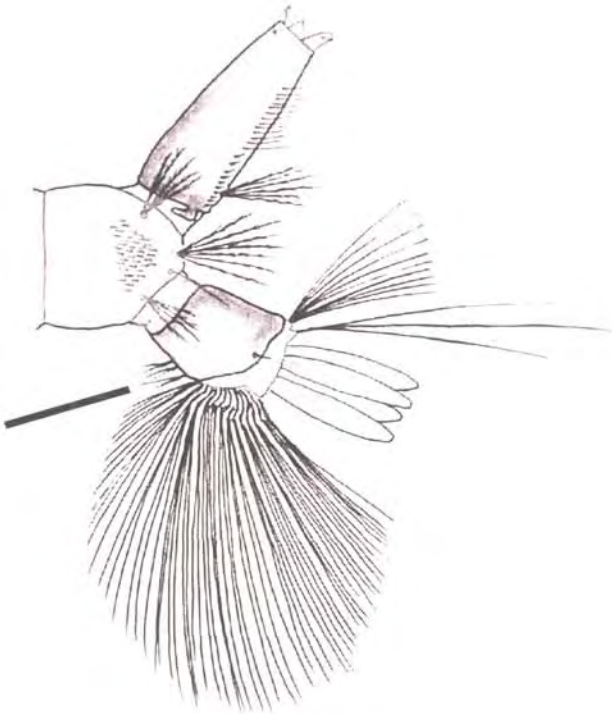


Figure 9-102.

Key to *Culex* Larvae

1 Siphon length 6 times or more than its basal diameter (Figure 9-103) . . . . . *Cx. territans, erythrothorax, salinarius, boharti*

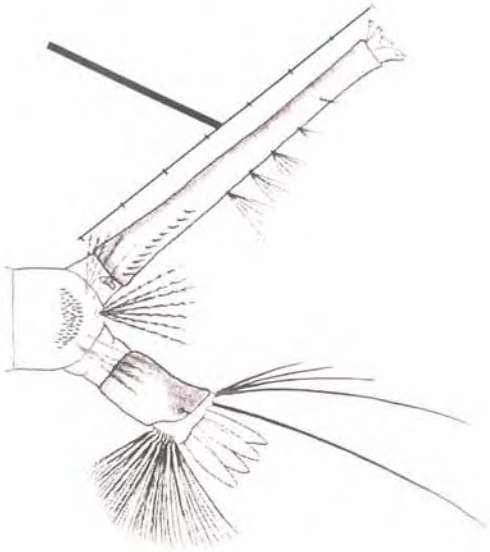
Siphon length 4 to 5.5 times as long as its basal diameter (Figure 9-104) 2

2(1) Siphon with 5 tufts, usually inserted in a straight line (Figure 9-105) . . *Cx. tarsalis*

Siphon with usually 4 single or branched tufts, with one or more out of line (Figure 9-106) 3

3(2) All siphonal tufts branched (Figure 9-107) . . . . . *Cx. pipiens*

Siphonal tufts represented by three long single hairs and a subapical tuft of two or three branches (Figure 9-108) . . . . . *Cx. restuans*



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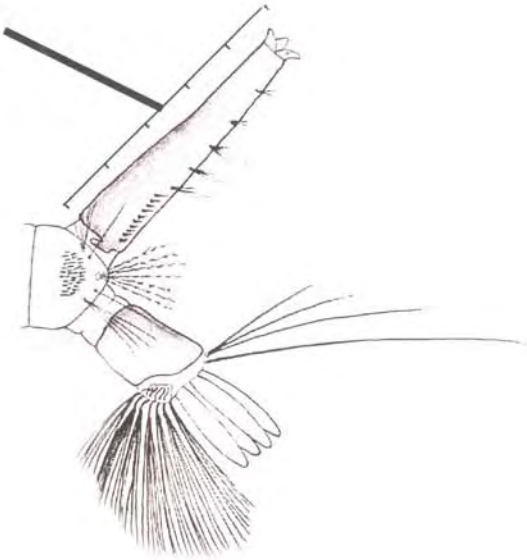

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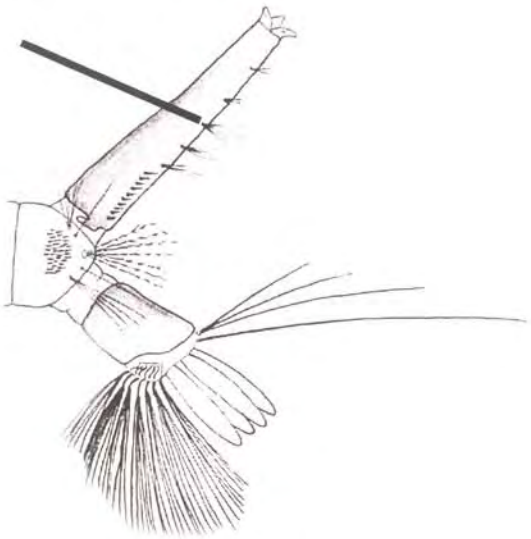

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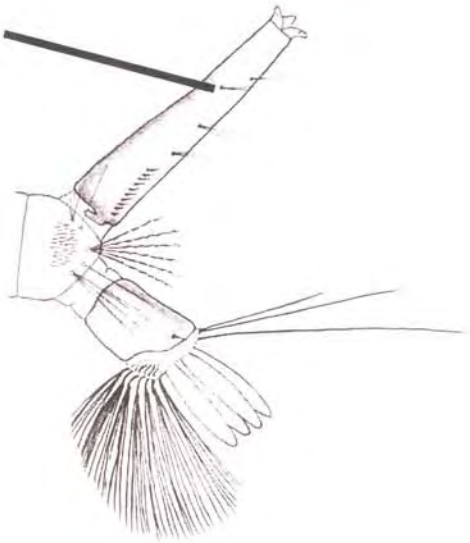

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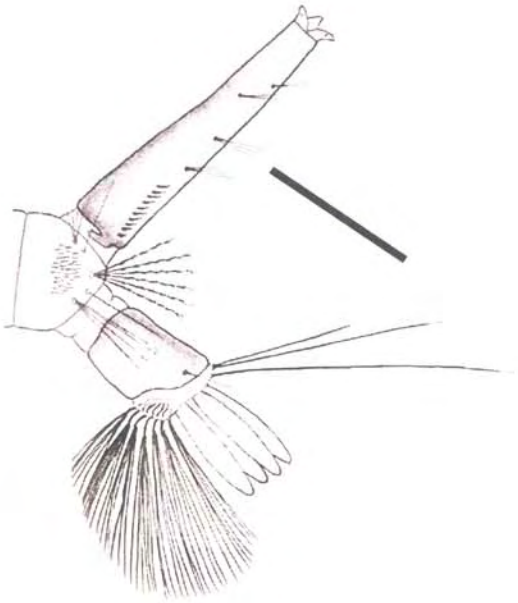

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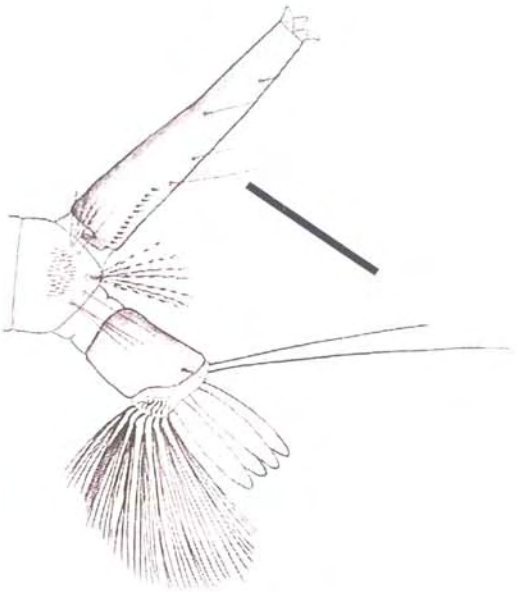

Figure 9-108.

10

Information Sources and Contacts

The purpose of this chapter is to provide additional information to supplement resources of those individuals interested in mosquitoes and their control.

Publications

The following is the only current general interest book on mosquitoes that can be recommended:

Mosquito by A. Spielman and M. D'Antonio; 2001; Hyperion, publisher; 247 pages.

Two good technical books on the biology of mosquitoes are the following:

The Biology of Mosquitoes - Volume 1 - Development, Nutrition and Reproduction by A. N. Clements; 1992; Chapman & Hall, publisher; 509 pages.

The Biology of Mosquitoes - Volume 2 - Sensory Reception and Behaviour by A. N. Clements; 1999; CABI, publisher; 740 pages.

The best technical identification guide for any mosquito that may be expected to exist in Idaho (other than the more recent *Aedes albopictus* [Asian Tiger Mosquito] and *Ochlerotatus japonicus japonicus* [Asian Bush Mosquito]) is out of print, but is worthy of mentioning in the event a copy becomes available. It is as follows:

Identification and Geographical Distribution of the Mosquitoes of North America, North of Mexico by R. F. Darsie, Jr. and R. A. Ward; 1981; AMCA Mosquito Systematics Supplement 1; 313 pages.

A current substitute for the southern half of Idaho is the following publication:

An Identification Guide to the Mosquitoes of Utah by L. T. Nielsen, R. J. Brand and G. C. Collett; 2001; UMAA, publisher; 97 pages.

A substitute for the panhandle portion of the state is the following publication:

The Mosquitoes of Canada (Diptera: Culicidae) by D. M. Wood, P. T. Dang and R. A. Ellis; 1979; Canada Department of Agriculture, publisher; 390 pages.

Two good publications for training purposes are the following:

Mosquitoes of Public Health Importance and Their Control by H. D. Pratt and C. G. Moore; 1993; CDC publication 3013-G; 85 pages; available from: URL: http://www.cdc.gov/ncidod/dvbid/westnile/education.htm.

Applying Pesticides Correctly: A Guide for Private and Commercial Applicators by the Ohio State University; 1992; 136 pages; available from: URL: http://www.uwyo.edu/plants/wyopest/TrainingManuals/Core.pdf.

Organizations

Association with any of the following three professional organizations will contribute to a better understanding of mosquitos and their control:

Utah Mosquito Abatement Association
2020 North Redwood Road
Salt Lake City, UT 84116
Phone: 801-355-9221
Fax: 801-355-9227
E-mail: glencollett@hotmail.com
http://www.umaa.org
http://www.umaa.org/nv1503.htm

American Mosquito Control Association
Post Office Box 234
Eatontown, NJ 07724-0234
Phone: 732-544-4645
Fax: 732-542-3267
E-mail: amca@mosquito.org
http://www.mosquito.org

Northwest Mosquito and Vector Control Association
521 First Avenue NW
Great Falls, MT 59404
Phone: 406-454-6920
http://www.nwmvca.org

Internet Links

As of May 1, 2003, there were approximately 925,000 websites mentioning mosquitoes. Five important links are the following:

http://www.mosquito.org/Links/sites.html

http://www.mosquito.org/MosqInfo/mosquito.html

http://www2.state.id.us/dhw/cdp/westnile/overallplan.pdf

http://www.mosquito.org/WNVteaser/WNVLinks.htm

http://www.cdc.gov/ncidod/dvbid/westnile/index.htm

Mosquito Control Chemicals and Equipment

(for professional application)

There are many companies that sell mosquito control chemicals and application equipment. The following companies will serve as an example. They were each represented at the 2002 annual meeting of the Utah Mosquito Abatement Association and have an interest in the area:

Chemicals

Clarke Mosquito Control Products, Inc.
159 N. Garden Avenue
Roselle, IL 60172
Phone: 630-894-2000
http://www.cmosquito.com

B&G Chemicals & Equipment Co., Inc.
1225 N. Post Oak Road
Houston, TX 77055
Phone: 713-682-4411
Fax: 713-682-4374
http://www.bgbugnet.com

Fennimore Chemicals
2800 S. Financial Ct.
Sanford, FL 32773-8118
Phone: 877-874-0390
Fax: 866-330-9888

Cheminova, Inc.
3323 198 Place S.E.
Bothell, WA 98012
Phone: 425-488-7801
Fax: 425-424-9114

Univar USA, Inc.
650 W. 800 S.
Salt Lake City, UT 84110-2369
Phone: 801-933-6132
Fax: 801-328-8797
http://www.univarusa.com

Cognis Corporation
5051 Estecreek Drive
Cincinnati, OH 45232-1446
Phone: 513-482-2814
Fax: 513-482-5512
http://www.cognisag.com

Application Equipment

B&G Chemicals & Equipment Co., Inc.
1225 N. Post Oak Road
Houston, TX 77055
Phone: 713-682-4411
Fax: 713-682-4374
http://www.bgbugnet.com

Adapco Solutions & Technology
2800 S. Financial Court
Sanford, FL 32773
Phone: 800-367-0659
Fax: 866-330-9888
http://www.e-adapco.com

ElectraMist, Inc.
P.O. Box 91
Cedars, PA 19423
Phone: 800-561-2204
Fax: 610-935-6447
http://www.electramist.com

London Fog
505 Brimhall Avenue
Long Lake, MN 55356
Phone: 952-473-5366
Fax: 952-473-5302
http://www.londonfoggers.com

Mosquito Fish

Currently, the use of mosquito fish, primarily the Western Mosquitofish (*Gambusia affinis),* is restricted in the state by the Idaho Department of Fish and Game. Distribution is limited to mosquito abatement districts (listed in Chapter 7 of this guide). Contact these agencies to obtain fish. An approved Idaho source is the following business:

Opaline Aquafarm
HC 79, Box 100
Melba, ID 83641
Phone: 208-495-2654
Fax: 208-495-2946

Mosquito Control Products for the Property Owner

Currently, only Mosquito Dunks® and similar products are approved for the control of mosquitoes in birdbaths, pools and ponds. The use of these products does not require an applicator's license. These are non-chemical products containing a bacteria that attacks only the immature mosquitoes and their close relatives. These products are harmless to humans, pets and fish when used according to container instructions. Mosquito Dunks® and similar products should be available at most local hardware stores and garden centers. True Value stores will special order the product for interested persons.

Mosquito Surveillance, Monitoring, Collection and Preservation Supplies

The following companies provide supplies for the serious mosquito specialist, including mosquito traps, larvae collection and sampling kits, rearing devices, collecting nets, mosquito fish nets, microscopes, mounting supplies and reagents:

Clarke Mosquito Control Products, Inc.
159 N. Garden Avenue
Roselle, IL 60172
Phone: 630-894-2000
http://www.cmosquito.com

BioQuip Products
2321 Gladwick Street
Rancho Dominguez, CA 90220
Phone: 310-667-8800
http://www.bioquip.com

John W. Hock Company
P.O. Box 12852
Grainesville, FL 32604
Phone: 352-378-3209
Fax: 352-372-1838
http://www.acceleration.net/whock

Aldrich
P.O. Box 2060
Milwaukee, WI 53201
Phone: 800-558-9160
Fax: 800-962-9591
http://www.sigma-aldrich.com

Federal Contacts

With regard to the control of mosquitoes in waters and wetlands of the state, and where mosquito breeding may occur on federal land, the following federal agencies may have an interest:

U.S. Army Corps of Engineers
Boise Office, Walla Walla District
P.O. Box 2780
Boise, ID 83701
Phone: 208-345-2064

Environmental Protection Agency
Idaho Operations Office
1435 North Orchard Street
Boise, ID 83706
Phone: 208-378-5746

U.S. Fish and Wildlife Service
1387 South Vinnell Way, Suite 341
Boise, ID 83709-1657
Phone: 208-378-5243

National Park Service
Bureau of Land Management
3380 Americana Terrace
Boise, ID 83706
Phone: 208-384-3000

U.S. Forest Service
Fish and Aquatic Ecology Unit
860 North 1200 East
Logan, UT 84321
Phone: 801-797-2500

Bureau of Reclamation
1150 N. Curtis Road
Boise, ID 83706-1234
Phone: 208-378-5020

State Contacts

The following Idaho agencies may provide assistance or information concerning mosquito control matters:

Idaho Department of Agriculture
P.O. Box 790
2270 Old Penitentiary Road
Boise, ID 83701
Phone: 208-332-8500

Division of Animal Industries
Phone: 208-332-8560
(oversees animal diseases caused by mosquitoes, consultation with veterinarians, health agencies and public regarding domestic animal health)

Urban Pesticide Program
Phone: 208-442-2803
(provides information and training on integrated pest management in mosquito control programs and oversees ULV spray equipment calibration)

Organic Program
Phone: 208-332-8620
(maintains a list of properties owned by certified organic growers which should be excluded from mosquito control pesticide application)

Apiary Program
Phone: 208-332-8620
(maintains records of registered beekeepers who should be made aware of mosquito control pesticide applications in their area)

Noxious Weed Program
Phone: 208-332-8667
(promotes biological control of noxious weeds using insects. Contact county weed superintendent for locations prior to spraying: http://www.idahoag.us/animal/weedintro.htm)

Idaho Department of Environmental Quality
1410 North Hilton
Boise, ID 83706-1255
Phone: 208-373-0502
(agency has multiple interests in protecting surface waters of the state under the federal Clean Water Act, which

includes stormwater control requirements for retention ponds and ditches)

Idaho Department of Fish and Game
P.O. Box 25
600 S. Walnut Street
Boise, ID 83707
Phone: 208-334-3700
(agency has an interest in the West Nile virus in wildlife, mosquito control on IDFG land [208-334-2920], and mosquito fish [208-334-3791])

Idaho Department of Health and Welfare
450 W. State Street
P.O. Box 83720
Boise, ID 83720-0036
Phone: 208-334-5500

Office of Epidemiology
Phone: 208-334-5939
(office monitors reportable diseases occurring in the state [including human diseases associated with mosquitoes], provides periodic press releases, and consults with other state and local agencies with similar interests)

Bureau of Laboratories
Phone: 208-334-2235
(Virology Section conducts tests associated with viral diseases, including biological samples from humans, horses, birds and mosquitoes which may be associated with the West Nile virus)

Idaho Department of Water Resources
1301 North Orchard Street
Boise, ID 83706
Phone: 208-327-7900
(agency has an interest in the distribution of water in the state and works closely with the Bureau of Reclamation, U.S. Army Corps of Engineers and Idaho Water Users Association on issues which may contribute to mosquito breeding)

Local Contacts

The following agencies may provide assistance or information concerning mosquito control matters at the local level:

District Health Departments

Panhandle District Health Department
2195 Ironwood Court
Coeur d'Alene, ID 83814
Phone: 208-667-3481
(provides public health services for the counties of Benewah, Bonner, Boundary, Kootenai and Shoshone)

North Central District Health Department
215 10th Street
Lewiston, ID 83501
Phone: 208-799-3100
(provides public health services for the counties of Clearwater, Idaho, Latah, Lewis and Nez Perce)

Southwest District Health Department
920 Main Street
Caldwell, ID 83605
Phone: 208-455-5300
(provides public health services for the counties of Adams, Canyon, Gem, Owyhee, Payette and Washington)

Central District Health Department
707 N. Armstrong Place
Boise, ID 83704
Phone: 208-375-5211
(provides public health services for the counties of Ada, Boise, Elmore and Valley)

South Central District Health Department
1020 Washington St. North
Twin Falls, ID 83303
Phone: 208-734-5900
(provides public health services for the counties of Blaine, Camas, Cassia, Gooding, Jerome, Lincoln, Minidoka and Twin Falls)

Southeastern District Health Department
1901 Alvin Ricken Drive
Pocatello, ID 83201
Phone: 208-233-9080
(provides public health services for the counties of Bannock, Bear Lake, Bingham, Butte, Caribou, Franklin, Oneida and Power)

District 7 Health Department
254 "E" Street
Idaho Falls, ID 83402-3597
Phone: 208-522-0310
(provides public health services for the counties of Bonneville, Clark, Custer, Fremont, Jefferson, Lemhi, Madison and Teton)

University of Idaho Extension
(There are 42 county extension offices in the state. The staff may provide assistance or information about mosquito control. To contact a local office, the phone number will be in the county government section under "Extension-University of Idaho.")

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About the Author

Donald R. (Don) Brothers collected his first mosquito in 1965 on a medical entomology field trip as an undergraduate student at San Jose State College. Since then, he has had more than a casual interest in mosquitoes and other animals of public health significance. He has provided assistance and consultation on mosquitoes and vector control for health agencies in California and Idaho and has written several journal articles.

Since retiring from a career in public health in 1999, he devotes considerable time studying various aspects of vector ecology. His latest contribution was collecting two mosquito species not previously known to exist in Idaho.

Mr. Brothers is currently assisting the Idaho Department of Health and Welfare with the West Nile virus surveillance program.

Don Brothers collecting the larvae of a treehole mosquito.