PUBLIC HEALTH PEST CONTROL

WASHINGTON STATE UNIVERSITY EXTENSION • EM034

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Preface

Public Health Pest Control covers the basic information on pest identification and biologies, and the management principles involved to control pests that potentially cause health problems in humans. This manual is designed as a study guide for those persons working or consulting in public health pest control, for those who use or recommend pesticides as a pest control option, and for those who must be licensed in the category of Public Health Pest Control. The Public Health Pest Control Exam administered by the Washington State Department of Agriculture is based on this study manual and information in Washington Pesticide Laws and Safety (EM012). This manual is not intended to give recommendations on pesticide use. Other reference and technical material is available for specific pest problems. All chemicals mentioned were available at the date of printing, but their status may change.

A prerequisite for understanding the information in this manual is the basic knowledge and understanding of pesticide laws and safety. See Washington Pesticide Laws and Safety (EM012).

A glossary is included to help familiarize you with key terms formatted in bold throughout the text.

AUTHORS

Carol A. Black, M.S., Extension pesticide education specialist, Washington State University, Pullman.

Rebecca Maguire, M.S., Extension pesticide education associate, WSU Puyallup.

Carrie Foss, M.S., Extension urban IPM director, WSU Puyallup.

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Introduction

Certain animals, most specifically **arthropod** pests (insects, spiders, mites, ticks), have caused weakness, illness, and even death in humans. Public health problems range from simple annoyance to transmission of disease-causing **pathogens** by a pest animal.

Public health pests affect humans in two ways. First, they can directly cause discomfort or disease. People may experience discomfort as fear of the pest animal or as annoyance, such as seeing, hearing, or smelling the pest. Pests can inflict **disease** by their presence, by feeding, or by stinging. Second, certain pests can transmit disease **organisms**. A **vector** is an animal capable of carrying a disease organism or **parasite** from one host to another. For example, a mosquito vectors West Nile Virus when it feeds on an infected bird, picks up the West Nile Virus, and transfers the virus to a subsequent host by feeding on that host. The most common mosquito species known to vector the *Zika* virus do not live in Washington.

The most common pests requiring attention by public health personnel include mosquitoes, flies, fleas, lice, bed bugs, cockroaches, wasps, ticks, mites, spiders, and rodents. Some of these (i.e., cockroaches, stinging insects, spiders, and rodents) cause discomfort or disease. Others (i.e., mosquitoes, fleas, and ticks) actually transmit (vector) diseases as well as cause discomfort.

Because pathogens exist, the threat of disease is present. Pest control becomes necessary when populations of public health pests reach a level where discomfort is intolerable or when potential disease problems become evident. For example, prior to West Nile Virus, disease incidence of animal or arthropod vectored diseases was low in Washington. Tularemia, encephalitis, lyme disease, relapsing fever, hantavirus, and plague also pose public concerns.

Successful control of public health pests, as with all pests, involves several steps:

1. Identify the pest and review its biology.
2. Determine the extent of the pest's presence.
3. Select the best control strategies for the pest infestation.
4. Implement control strategies.
5. Evaluate the effectiveness of the control measures.

Base control measures on a good working knowledge and understanding of pertinent technology and safety precautions. The entire control program must reflect the current legal situation.

Pest identification is of great importance to pest control. You must be certain that the organism in question is the one causing the problem and that it needs to be controlled. This manual will present public health pest identification, pest biology, and other significant information relating to public health pests.

Surveys are essential for evaluating pest populations. Attempting to control arthropods or rodents without determining the **species** involved, population densities, infestation sources, and the biology and **ecology** of the pests is irresponsible and frequently leads to instituting unnecessary control measures and **pesticide** misuse.

Once an evaluation is complete and control measures are deemed necessary, evaluate the available management options, which may include:

- **Resource Management / Environmental Manipulation**—Managing food, **habitat**, water, and land to minimize or eliminate pests. This is one of the more desirable methods for controlling pests because it usually has the least negative impact on people and nontarget animals.

- **Prevention / Mechanical Barriers**—Using screens, netting, and protective clothing to protect people from biting and nuisance insects. Good construction and barriers also keep pest animals out of structures.
- **Biological Control**—Encouraging **predators** and **parasites** that feed on pest animals to control pest populations. Once the beneficial organism is established, biological control is self-sustaining. However, biological control will not eradicate pests because the beneficial organism depends on the presence of the pest species for survival.
- **Chemical Control**—Applying natural or synthetic pesticides formulated to control pest populations. These pesticides include both chemical compounds and biological organisms that kill or repell pest organisms.

Integrated pest management (IPM) offers the possibiity of improving the efficiency of pest control programs while reducing negative impacts. IPM uses a combination of biological, environmental, and chemical control methods. Controlling pests by stressing nonchemical methods should be the goal of pest management programs. Use pesticides to complement, not supplement, nonchemical control methods. Nonchemical control methods can reduce the population level before chemical control is initiated.

Eradication of pest populations is generally not possible, nor is it biologically or economically desirable. A good pest control program should reduce pest populations to levels acceptable to the public.

Regulations for Public Health Pest Control

FIFRA

Regulation of pesticides at the federal level is conducted by the Environmental Protection Agency (EPA) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The major regulations set up under this act are discussed in the manual Washington Pesticide Laws and Safety (EM012).

Washington State Regulations

In addition to the state pesticide laws discussed in Washington Pesticide Laws and Safety, several regulations are in place to protect the environment and public health from the use of pesticides in water or for the control of certain wildlife. State legislation governing the use of chemicals in water primarily falls under the guidance of the Washington State Department of Agriculture (WSDA) and the Washington Department of Ecology (Ecology). Laws that regulate the control of wildlife are administered by the Washington Department of Fish and Wildlife (WDFW).

Washington State Department of Agriculture

All pesticide formulations labeled for application onto or into water to control aquatic pests are designated state "restricted use" pesticides. Pesticide applications to or onto water shall be made only by applicators certified in Aquatic Pest Control, Aquatic Pest Control-Irrigation, or Public Health Pest Control and only for those pests covered by that certification.

Washington Department of Ecology

Under Washington State Surface Water Quality Standards, it is illegal to place any pesticide in water unless permission has been granted by Ecology. Get information on aquatic pesticide general permits for mosquito control from http://www.ecy.wa.gov/programs/wq/permits/genpermits.html.

Washington Department of Fish and Wildlife

Complex legal wildlife codes guide the WDFW in its wildlife management programs. In certain situations, such as when a protected species becomes a pest, WDFW may remove protections. State laws specify control methods and procedures that can be used when confronted by damage from wildlife species not protected by federal law. Contact WDFW before using any lethal methods to control pest game animals. Nongame pest animals not protected by laws may be controlled without a WDFW permit or license.

When choosing wildlife depredation control methods, be aware of local regulations. For example, the use of scare devices based on noise may conflict with ordinances prohibiting disturbing the peace.

Contact WDFW if *Gambusia* is to be used for mosquito control or if wildlife, inland, or saltwater fish might be in jeopardy from an aquatic pest management approach.

Other Agencies

Several other agencies have jurisdiction over pest control. Ecology may contact these agencies to review information on the "permit" application forms. Pesticide applicators may need to work with these agencies if pesticide applications are made in areas under their authority.

- Washington Department of Natural Resources—Inform if endangered species or their habitats fall within the proposed application site.

- Local or City Planning Agencies—If required, send aquatic permit application forms. Agencies may request inclusion of special restrictions in the permit. Some cities and counties have additional permit requirements for aquatic pesticide applications.

Human Disease Concerns

One of the reasons a pest can become a public health issue is because of its ability to transmit human diseases. Being familiar with the disease risks, how they are transferred to humans, their symptoms, and techniques to avoid exposure makes you a better pest manager.

Disease Transmission, Symptoms, and Protections

Several diseases occur in problem pest populations that can impact humans. A pest manager must understand how different diseases move from infected animals to humans. Precautions vary according to the disease, geographical location, pest animal being managed, and control method. There are several major pathways by which disease organisms pass from animals to people.

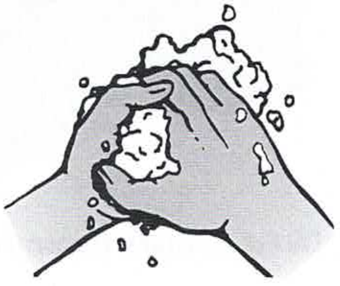
Transmission Pathways and Diseases

- **Ingestion:** Leptospirosis, intestinal bacterial diseases
- **Inhalation:** Hantavirus
- **Wound Penetration (bites, cuts):** Tetanus, Leptospirosis
- **Vector-borne (fleas, mosquitoes, ticks):** Plague, Rocky Mountain spotted fever, West Nile virus, Lyme disease, Tularemia, Relapsing fever

Fecal-oral Transmission

A disease organism that lives in a wild animal can be excreted as a living organism in the animal's feces or urine. If the contaminated feces are touched or someone handles objects contaminated with fecal material or urine and then touches their mouth or ingests contaminated water, disease transfer can occur.

To prevent disease transmission, wear disposable or washable gloves when handling animals, objects, or soil that may be contaminated with feces or urine. Practice good hygiene by washing your hands after contact with these items, using the toilet, smoking, talking on cell phones, and before eating or handling food. Avoid food and water that might be contaminated or use water purification measures prior to drinking water. Disinfect cages, traps, and other items contaminated with animal feces or urine.



Respiratory Transmission

Respiratory transmission of disease occurs when disease organisms in urine, feces, or other animal material become airborne and are inhaled by humans. Work in a manner to limit disturbing areas to avoid causing contaminated particles from becoming airborne. If working in an area with an accumulation of mice, bird, or bat droppings, wear disposable clothing and an appropriate National Institute for Occupational Safety and Health (NIOSH) dust/mist respirator. Disinfect the area by spraying it with a 10% bleach solution. (A 10% solution corresponds to $1^{1}/_{2}$ cups of household bleach per gallon of water, or 1 part bleach to 9 parts water.) Wear clean rubber gloves and wash them at the end of each work day.

Disinfect or replace all traps or similar devices. When handling dead animals, spray them with a disinfectant solution, seal in one bag, and place that bag into a second sealed bag. Contact your local health agency for the proper disposal method.

Direct Contact Transmission

Simply handling animals and contacting tissues or fluids that contain disease organisms can result in disease transmission. Wear rubber or plastic gloves for protection and keep any skin from coming into contact with live or dead animals or their nesting material. Practice good hygiene—especially hand-washing—for protection.

Wound Penetration

Some diseases require a break in the skin, such as an animal bite, scratch, puncture, or other injury. Stay current on your tetanus immunization. Some vaccines—like rabies—help protect wildlife managers both before and after an exposure occurs.

Vector-borne Transmission

Sometimes another organism, like a flea, tick, or mosquito, transfers disease from an infected animal to humans. Insect and tick repellents may provide some personal protection. Spray animal carcasses with an **insecticide** and double bag if large numbers of fleas or ticks are present.

Contact a medical provider if you experience any symptoms (e.g., fever, headache, fatigue) after handling live or dead animals or working in areas with animal nests, urine, feces, or other contaminated surfaces. Inform the physician of your possible exposures to animals. Be specific about the animal species handled and any other exposure to possible disease vectors, and characterize the environment in which you have been working. Diseases contracted from wildlife or outdoor exposures are relatively rare and most physicians do not readily recognize the symptoms. Early medical attention is critical for successful treatment.

Transmittable Diseases

The following diseases may be present in pest animals or areas where they live. Be aware of the symptoms for diseases to which you could be exposed and possible medical treatments. Identify ways to avoid or minimize exposure. Consult state and local health departments for specific disease concerns in your area.

Hantavirus

The Sin Nombre virus, also known as **hantavirus**, causes extremely serious respiratory illness (Hantavirus Pulmonary Syndrome (HPS)). The virus is primarily found in the dried urine, saliva, and droppings of deer mice. It is contracted by humans when they breathe contaminated dust particles. Transmission can also occur after handling deer mice and then touching your nose or mouth, or by a rodent bite. Symptoms include fever, muscle aches, and difficulty breathing. In addition, some people experience headaches, coughing, nausea, vomiting, diarrhea, and stomach pains. Symptoms typically start in 3 days to 6 weeks after exposure. There are no effective medications; however, early hospital care is critical to treat the symptoms.

Intestinal Bacterial Diseases

Several organisms are classified as **enteric** bacteria when they reside in the intestines. *Campylobacter sp., E. coli,* and ***Salmonella*** sp. are normal inhabitants in the intestines of many warm-blooded animals, but can cause campylobacteriosis, *E. coli* infections, and salmoneliosis in humans. Humans can contract these intestinal disorders after handling, eating, or drinking contaminated food or water, or not washing their hands or food after contact with animal feces. Handling reptiles, chicks, or ducklings is a significant risk factor for salmonella. Raw poultry, milk, and vegetables are the more common routes of exposure. Symptoms include severe diarrhea, fever, and traces of blood in feces 2–5 days after exposure. Medical treatment is available. Practice good hygiene for protection.

Leptospirosis

This is a bacterial disease, also known as Weil's disease. The bacteria reside in moist soil or water or on vegetation contaminated with fresh urine from infected animals (e.g., rats, raccoons). Humans become infected through contact with water, food, or soil containing urine from infected domestic or wild animals. Symptoms vary in severity, and include sudden fever, chills, headache, body aches, and fatigue from 4 to 19 days after exposure. **Leptospirosis** may affect the liver, kidneys, or nervous system. Medical treatment is available. Practice good hygiene for protection.

Lyme Disease

Lyme disease is caused by the bacterium *Borrelia burgdorferi,* which resides in the midgut of ticks. In Washington it is transmitted through the bite of the western black-legged (or deer) tick *(Ixodes pacificus)*. These ticks commonly feed on mice, squirrels, and other small animals. The Pacific Northwest is a low-risk area for Lyme disease.

The first sign of Lyme disease is usually a circular rash that occurs at the tick bite location and gradually expands up to 12 inches across. People that are infected may also experience fatigue, chills, fever, headache, muscle and joint aches, and swollen lymph nodes. Other symptoms can develop with long-term effects. Protect yourself from tick bites by wearing appropriate clothing and using insect repellents. Also conduct daily tick checks of your body when working in tick habitat. Seek medical attention if experiencing symptoms since long-term disabilities can result from infection.

Plague

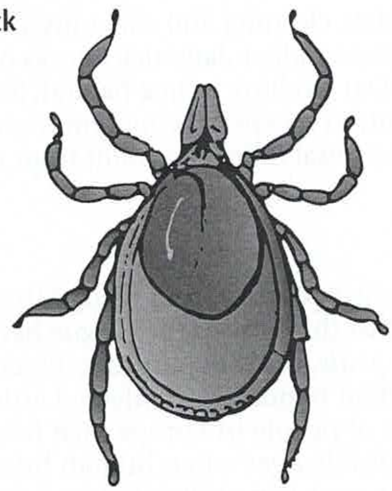
Humans get **plague** from being bitten by a rodent flea that carries the plague bacterium *Yersinia pestis*, or by exposure to tissues and fluids when handling an infected animal. Millions of people in Europe died from plague in the Middle Ages when human homes and places of work were inhabited by flea-infested rats. Fleas seek another warm-blooded host when their host dies. Today, modern antibiotics are effective against plague, but if an infected person is not treated promptly, the disease is likely to cause illness or death. Symptoms include swollen lymph glands accompanied by pain experienced 2–6 days after infection.

In the western United States, 1–40 cases are reported annually; most cases occur in New Mexico, Arizona, Colorado, and California. Be careful when handling live or dead ground squirrels, prairie dogs, and other burrowing rodents, which are the primary **reservoirs** for the disease. If working in an area with endemic plague, consider treating any animals with insecticide spray or dust and double bagging the potential carriers prior to handling and disposing of them.

Rocky Mountain Spotted Fever

The bacteria ***Rickettsia*** *rickettsii* is transmitted by the Rocky Mountain wood tick *(Dermacentor andersoni)*, American dog tick *(D. variabilis)*, and many other tick species. These ticks are primarily found on rodents, dogs, and deer. *Rickettsia rickettsii* transmission can occur either from a tick bite (and attachment for several hours) or a crushed tick that is exposed to cuts in your skin. The Pacific Northwest has relatively few cases. Symptoms include a sudden onset of moder-

Deer Tick



ate to high fever, accompanied by fatigue, deep muscle pain, severe headaches, chills, and eye infection. A rash appears on the wrists and ankles, and then spreads to the back, arms, legs, chest, and abdomen. Symptoms may last for 2–3 weeks. Early treatment with antibiotics is effective, but hospitalization may be required. Carefully remove ticks as soon as possible and remember to wash your hands promptly.

Recognize tick habitat, which are areas with rodents, deer, and any other host. Ticks only spread by physically grabbing another host species; thus, they primarily reside along game and rodent trails. When working in areas with host animals, inspect your body and remove any crawling or attached ticks. Wear light-colored clothing to more easily spot them. Wear long-sleeved shirts and long pants tucked into your sock legs to minimize exposed skin. Apply tick repellent, like **DEET**, to exposed skin and/or wear permethrin-treated clothing.

Tetanus

Tetanus is caused by the bacterium *Clostridium tentani*, which occurs in soil contaminated with manure. It affects the nervous system and causes painful tightening of the muscles all over the body. It is commonly called lockjaw. The greatest concern comes from exposure through a puncture wound, such as a contaminated barbed wire cut or nail. There are reports of transmission by animal bite. Due to tetanus immunizations, this disease is rare. Pest managers must stay current with their vaccinations.

Tularemia

Tularemia is a potentially serious illness. It is caused by the bacterium *Francisella tularensis*, which is most commonly found in rodents and rabbits. Tularemia is fatal to animals and is transmitted by ticks and deer flies, direct contact with infected animals, and contaminated water. Animals with this disease may be sluggish, unable to run when disturbed, or appear tame.

Tularemia can be transmitted to humans from the bite of an infected deer fly or tick, breathing in bacteria, drinking contaminated water, eating undercooked contaminated meat, or allowing an open cut to contact an infected animal. The most common source of tularemia for humans is to be cut or nicked by a knife when skinning or gutting an infected animal. Mowing over dead animals can also be a risk factor. Tularemia is not known to be spread from person to person. Symptoms include a high temperature, headache, body ache, nausea, and sweats. The disease can be fatal if not treated with the right antibiotics. Use a multi-tactic approach to prevent exposure, including insect repellents, good hygiene, and wearing gloves and a respirator.

West Nile Virus

West Nile virus is most prevalent in bird populations; it is transmitted by mosquitoes from birds to humans and other animals. Many people do not exhibit any symptoms. While 20% of infected humans have moderate symptoms (e.g., headache, fever, tiredness, body aches, and skin rash on trunk), fewer than 1% contract full meningitis or **encephalitis** (spinal column or brain swelling), which is often fatal. Practice prevention by avoiding mosquito habitats or protecting yourself from mosquito bites. Recognize symptoms (high fever, severe headache, nausea, stiff neck, confusion) and seek medical attention at their earliest onset.

Web Resources for Diseases

Oversight agencies

- Centers for Disease Control and Prevention: www.cdc.gov/az/a.html
- Washington State Department of Health: www.doh.wa.gov/a-z_topics/a.htm

Specific diseases

- **Hantavirus:** www.doh.wa.gov/YouandYourFamily/IllnessandDisease/Hantavirus
- **Leptospirosis:** www.cdc.gov/leptospirosis/
- **Lyme Disease:** www.cdc.gov/lyme/
- **Plague:** www.cdc.gov/plague/
- **Rocky Mountain Spotted Fever:** www.cdc.gov/rmsf/index.html
- **Tularemia:** www.cdc.gov/tularemia
- **West Nile Virus:** www.doh.wa.gov/YouandYourFamily/IllnessandDisease/WestNileVirus

Entomology

Many insects and their close relatives cause major problems to humans by direct injury, damage to food and fiber, or transmitting disease organisms.

Insect Growth and Development

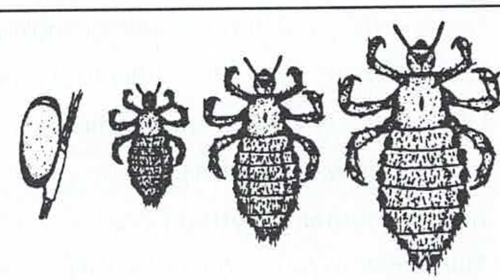
Insects and their relatives (e.g., mites, spiders, and shrimp) are segmented animals. Instead of an internal bone skeleton like mammals and many other animals, insects have an external covering called an **exoskeleton** (external skeleton). Although exoskeletons vary in hardness (think of an aphid as compared to a beetle), their chemical makeup is fairly uniform. For an insect to grow, it must periodically shed its exoskeleton and form a new one. It accomplishes this through a complicated chemical process called molting. All insects and their relatives grow through the molting process. The number of times an insect molts is specific to the type of insect. Each growth stage of an immature insect is called an **instar**. Thus, after hatching from an egg, the insect is called a first instar. After the first molt, the insect is called a second instar, and so on until it molts into an adult.

Most insects begin their lives as eggs. The female insect usually deposits her eggs in an appropriate place for the emerging young to develop (e.g., on food plants, in pools of water, or into plant tissue). Upon hatching from the egg, most insects develop and complete their **life cycle** in one of two ways—by complex or simple **metamorphosis**, which means to change form.

Simple Metamorphosis

Insects exhibiting **simple (or gradual) metamorphosis** pass through egg, nymph, and adult stages. The young insects are called **nymphs**. The female lays an egg, which hatches into a first instar nymph. The nymph molts several times during its lifetime, growing larger with each molt. Once the individual becomes an adult, it no longer molts or grows larger.

Grasshoppers, crickets, cockroaches, and lice are examples of insects that go through simple metamorphosis. The individuals that hatch from these eggs look very much like a small version of the adult. The most visible difference between nymphs and adults is that nymphs do not have fully formed wings. Adults and nymphs usually appear together on the same food plants or in the same habitat.

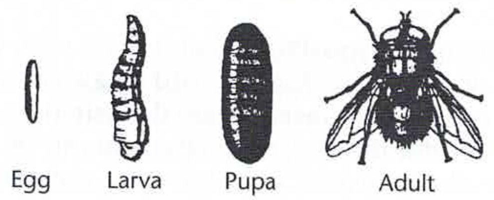


Life Cycle of the Head or Body Louse

Complex Metamorphosis

Insects that go through **complex (or complete) metamorphosis** transition from egg, larva, pupa, to adult life stages. In contrast to simple metamorphosis, with complex metamorphosis the insect young is a **larva** that looks nothing like the adult. The larvae and adults often live in different habitats and feed on different food sources. Examples of insects that undergo complex metamorphosis include butterflies, mosquitoes, flies, and fleas.

Most insects exhibiting complex metamorphosis begin as eggs. Upon hatching, the larva feeds and molts several times until it is ready to change into an adult. However, due to the extensive changes which must take place in structure, the larva often forms a pupal case (or **cocoon**) in which the **pupa** forms. During this pupal stage (lasting from a few days to several months), the body of the larva transforms into an adult. Eventually, the pupal case splits and the adult insect emerges.



Life Cycle of the Blow Fly

Arachnids include ticks, mites, scorpions, and spiders. They have four pair of legs, two body segments (the cephalothorax and the abdomen), and no antennae. Except for certain mites, arachnids are carnivorous and terrestrial. The life cycles of arachnids are variable and complicated. The tick, for example, has a life cycle with each stage requiring a different host. Some ticks require three different hosts for a life cycle that may take up to 3 years to complete; others may require only one or two hosts.

One must be able to properly distinguish and identify arthropods regardless of the stage of development. Proper identification and an understanding of arthropod life cycles are essential for effective pest management.

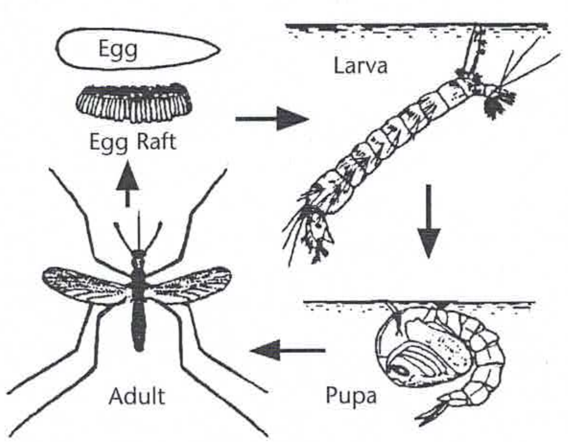
Mosquito Biology and Control

Mosquitoes annoy humans and domestic animals and subsequently affect the recreational and agricultural sectors of the economy. Some mosquito species are vectors of arthropod-borne encephalitis in the Northwest. West Nile Virus was first documented in Washington in the fall of 2002. Washington does not have the mosquito species that vector the *Zika* virus. Control measures are undertaken to reduce the annoyance suffered by the public. Essential to any mosquito control program is a thorough understanding of disease potential, mosquito identification, life cycles, and habitats.

Biology

Mosquitoes are distinguished from other closely related flies (midges and crane flies) by two main characteristics: 1) numerous scales on their bodies, wing veins, and wing edges, and 2) females that have a distinct blood-sucking **proboscis**. Mosquitoes undergo complete metamorphosis, developing from eggs to larvae to pupae to adults. The first three life stages are associated with water.

Adult males and females feed on plant juices and nectar for maintenance energy. Male mosquitoes do not bite humans. However, females require a sizable blood meal as a protein source to produce viable eggs. They primarily obtain blood from mammals, birds, and reptiles. Some mosquitoes have preferences as to the type of animal they will feed on and at what time of day. Females live longer than males and can produce multiple batches of eggs.



Life Cycle of the Mosquito

Egg-laying (**oviposition**) habits vary with the kind of mosquito. Eggs are laid singly or in rafts on water surfaces, or are deposited singly near a water holding area. Eggs laid out of the water are placed just above the waterline in natural or artificial containers where they hatch with the rise in the water level. They also can be placed in ground depressions where they hatch after being immersed by flood, irrigation, or melting snow waters. Eggs placed on water surfaces hatch after an incubation period of several days. Eggs deposited out of the water hatch under a variety of conditions; most hatch when the dissolved oxygen content of water is at the proper level, or when the summer **diapause** is broken by exposure to low temperature, as is the case with snow-water mosquitoes. As a general rule, mosquito species that oviposit on water surfaces over winter as adults, while species ovipositing on nonflooded substrates overwinter as eggs. One characteristic common to all mosquito egg deposition is that the ovipositing female must be protected from waves and strong wind currents.

Mosquito larvae ("wrigglers") live in still water and are adapted to all aquatic habitats except fast, flowing streams, and the open waters of large lakes and seas. Almost any type of water catchment will support larval development: saltwater or freshwater marshes, swamps, and margins of ponds or lakes. Larvae can develop in any contained water, such as potholes, ditches, old tires, cans, catch basins, and flooded pastures when water is present long enough for development of the immature stages. Emergent aquatic vegetation in large bodies of water is important to protect the larvae from waves.

Mosquito larvae obtain food from water, feeding on algae, bacteria, yeast, fungi, and protozoans. Most have air tubes ("siphons") near their tail by which they acquire air from the calm water surface, but *Coquillettidia* species puncture submergent vegetation with their siphons and obtain air from these plants.

Larvae undergo four developmental instars to increase their size prior to pupation. Larval development is usually completed in 4 to 10 days. Many chemical, physical, and biological factors in water affect mosquito larvae, including temperature, movement, light, dissolved gases and minerals, the presence of other organisms, and surface movement and tension.

Pupae ("tumblers") resemble a large comma with a pair of breathing tubes on their thorax. Pupae do not feed, but unlike most insect pupae, remain quite active. The pupal stage lasts around 3 days, depending upon water temperature (eggs, larvae, and pupae develop faster under warmer water temperatures).

Adults split their pupal skins, emerge, rest on the water surface as their skins harden and their wings dry, and then fly away in pursuit of a mate. Mosquito flight ranges vary from a few yards to many miles, depending upon the species and nature of the area. However, most mosquitoes fly no more than one or two miles unless dispersed by wind currents. Adults tend to stay close to the ground in vegetation and dense shrubbery if the wind is blowing or if the humidity is low.

The life span of mosquitoes is variable. Male mosquitoes generally live 7 to 10 days while females live from 2 weeks to several months, particularly female mosquitoes that are hibernating. Most Washington mosquito species are capable of producing multiple **broods** during the summer season, providing water is available and other habitat factors are favorable. An exception is the high mountain snow-water mosquito, *Aedes communis*, which has a single brood generation each season.

Five major groups of mosquitoes live in Washington: *Aedes, Culex, Culiseta, Coquillettidia,* and *Anopheles*. Each of these groups has characteristics to distinguish it from the others. Different mosquito species live in different habitats. Most control procedures are directed against the larval or adult stages. Applicators should be able to associate the more common pest species with their larval habitats, especially if control is targeted at the larval stage. West Nile virus is vectored by mosquitoes found in Washington, but *Zika* virus is not.

Mosquito Habits and Habitats

Group	Overwinter As	Eggs Laid	Larval Habitat	Other Information
Aedes	eggs or larvae	singly on ground or above water level in objects that can hold water	temporary & snow melt pools, irrigation & flood water, tree holes, and artificial containers	most common mosquitoes, larvae position diagonal to water surface
Culex	adult females	rafts on water	still, stagnant water; polluted water in ponds, catch basins, flooded fields, artificial containers, etc.	commonly found around cities & towns in association with humans, larvae diagonal to water surface
Culiseta	adult females	rafts on water	clean water in artificial containers, ponds, etc.	relatively large mosquitoes, larvae diagonal to water surface
Coquillettidia	larvae	rafts on water	pools with vegetation, freshwater marshes	larvae remain below water surface, acquire oxygen through plants by penetrating air tubes
Anopheles	adult females	singly on water, eggs have floats	impounded pools, seepages with vegetation, water in the sun or shade	larvae lie horizontal to water surface, not diagonal like others

The behavioral patterns of adult mosquitoes, including feeding habits, attraction to light, flight strength, and host preference relate to their importance as disease vectors or nuisances to people.

Surveys

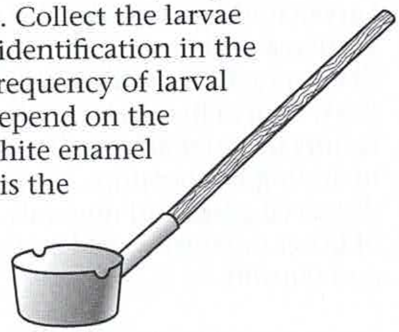
One of the most important elements of a successful mosquito control program is a good survey. Surveillance includes the detection of mosquito problems, species identifications, counts, and location mapping. Surveys provide information for management decisions, such as when to control and what method to use for each situation. Use surveys to determine control measure success.

Maps are essential for conducting mosquito surveys. Use a master map to provide an overview of all control operations showing larval producing areas, larval and adult sampling stations, the distribution of important vector species, and type of control activity. Aerial photographic maps, contour maps, and general area maps are useful.

Adult mosquito surveys indicate the distribution and abundance of various mosquito species at any one time. A variety of methods must be used to sample adult mosquito populations because of variation in habits of different mosquito species. Light traps, animal bait traps, CO_2 traps, sweep nets, and aspirators are examples of equipment used to collect adult mosquitoes. Biting collections, with the collector serving as the host, is one method of sampling mosquitoes that bite humans. Collections from natural and artificial resting stations (daytime shelters) are useful for sampling evening and nighttime feeders.

Adult mosquito collections can be used to predict problem populations after reviewing information on the type of larval habitat and other biological data for that particular mosquito species. Survey personnel must understand the natural history of those species collected. The data from trap sampling stations can be used to determine the effectiveness of mosquito control programs.

Larval surveys furnish data on the sources and exact acreage of mosquito-producing habitat, on the species present, and on their relative abundance. Since mosquito larvae are adapted to almost all aquatic habitats, map and record all areas sampled. Collect the larvae and preserve for identification in the laboratory. The frequency of larval surveys should depend on the time of year. A white enamel or plastic dipper is the most commonly used device for collecting and counting mosquito larvae.



Sample for mosquito larvae presence before any **larvicide** is applied to aquatic habitats. Conduct post-treatment larval sampling on a specific time schedule to determine the effectiveness of treatment over a period of time.

Take mosquito egg surveys occasionally to determine production sources for flood, irrigation, and snow water mosquitoes. These surveys can indicate potential adult population densities based on egg abundance. There are two ways of conducting egg surveys—by collecting a standard square area of sod or debris from habitat that is subject to water inundation. In one method, separate and identify eggs. In the other method, place the sod in a container with water and then count and identify the larvae as they hatch.

Management and Control

Once the surveys are completed and the numbers and species are such that control is warranted, choose a safe and effective control method. The term **abatement** is used in place of control for mosquito management because populations will not be eliminated. Abatement programs reduce the numbers of mosquitoes to an acceptable level.

Mosquito numbers can be reduced by water management, mechanical barriers, biological control agents, and pesticides. Abatement programs usually incorporate an integrated approach by using multiple suppression strategies based on the situation.

Water Management

Water management is the most widely used and most ecologically sound approach to mosquito control. This method involves many techniques designed to eliminate excess surface water or to manipulate water systems. Four basic principles are involved in water management.

1. **Eliminate mosquito breeding habitat:** remove excess surface water within 5 days of accumulation; clean and replenish troughs, pools, ponds, and birdbaths; cover water sources.
2. **Prevent water accumulation:** use proper design and maintenance of drainage ditches and gutters; fill or grade pool-forming areas; eliminate temporary water containers.
3. **Use predaceous fish as biological control:** Increase the amount of standing water to create a suitable habitat or construct a means of access for these fish into and out of mosquito breeding sites.
4. **Increase water movement:** create stress conditions for mosquito larvae and pupae in their breeding areas; mosquito larvae cannot tolerate much water movement.

Mechanical Barriers

Ordinary 16-mesh window screens will prevent most mosquitoes from entering dwellings. Air screens or air curtains are used with varying success in commercial establishments to keep winged insects from entering while allowing free access for people.

Mosquito netting has utility in recreational areas where mosquitoes and other biting flies pose a problem. Clothing of tightly woven material provides some protection from mosquitoes.

Biological Control

One of the most successful mosquito predators is *Gambusia affinis,* a top-feeding minnow with a voracious appetite for mosquito larvae. It is been very effective in controlling mosquitoes but can also be a major pest when it feeds native fish and amphibians, including the egg, larvae, and juvenile life stages. For this reason *Gambusia* is a regulated species and can not be introduced without a fish stocking permit from WDFW. Currently, WDFW policy is to issue permits to organized mosquito control districts, the U.S. Army Corps of Engineers, and city, county, or state health departments. Permits are not issued to private individuals.

Chemical Control

When other control measures cannot maintain a tolerable population level and an outbreak has occurred or is imminent, chemical control is necessary. Chemical control of mosquitoes is generally targeted at larvae and adults.

Insecticide groups used for mosquito control include larvicides (l) and **adulticides** (a). Common names of some chemicals registered for use in Washington follow:

- Petroleum distillates—act by inhalation of toxic components through the insect respiratory system or by suffocation: oils and oil solutions (l)
- Botanicals and synthetic pyrethroids—classified as contact poisons that interfere with the insect's physiology. They do not exhibit lengthy residual action: bifenthrin (a), cypermethrin (a), resmethrin (a), phenothrin (a) (almost always used in combination with other active ingredients)
- Organophosphates—inhibit cholinesterase, resulting in over-excitation of the nervous system: malathion (a,l), temephos (l)
- Other neural toxins—acetamiprid (a), spinosad (a)
- Growth inhibitors—disrupt normal development and maturation of immature insects: methoprene (l), cyromazine (l)

- Insect pathogens—stop digestion, resulting in death: *Bacillus thuringiensis* var. *israelensis* (l)

Larvicides. Mosquito larvicides kill mosquito larvae. They are applied to water or to low areas regularly subject to flooding. Extreme care is essential when using insecticides to control mosquito larvae. Continue surveying so you can apply larvicides before population growth exceeds a tolerable level. Apply only to areas where mosquito larvae are present. Apply as soon as surveys show a developing mosquito population. Younger larvae are more susceptible to chemical control. Larvae generally live in pond or lake margins—treat these areas only. Sample the population shortly before using abatement measures to confirm the need.

Most larvicides work by toxic action or suffocation. Granules release toxicants and are extremely useful in very early spring or when spot treating areas with dense foliage. Oils act by either suffocation or lethal larval inhalation. Oils applied in small amounts are relatively safe to other organisms and can be used in sensitive areas, but **phytotoxicity** can result. Oil solutions consist of an active ingredient mixed with an oil base for more uniform applications. They do not evaporate quickly and are preferred when the applicator depends on drift for coverage. Emulsifiable concentrates are designed to be diluted in water; the droplets do not persist in the air as long as oil formulations.

Growth inhibitors mimic an insect's own hormones, resulting in interference with normal development. They tend to be effective only at certain stages of immature development. Mosquito larvae exposed to growth inhibitors at a sensitive period will not develop to the adult stage.

Bacillus thuringiensis var. *israelensis* (Bti) is a species of bacteria that are lethal when mosquito larvae ingest them. The bacterium produces a toxin that crystallizes the mosquito larval gut, resulting in larval death. It is available in several insecticide formulations and can be applied with various application equipment.

Before making any applications to water, you must have a National Pollutant Discharge Elimination System (NPDES) permit from the Washington State Department of Ecology.

Adulticides. Sometimes targeting mosquito larvae is not possible or effective, and large populations of adults occur. For instance, if many acres of mosquito breeding sites surround a small town, park, or camp, usually larvicides are not an economical management approach. Sometimes adult mosquitoes which have been only a minor nuisance become a major annoyance or a public health problem as disease vectors. Under these situations, various adulticide applications may be necessary. Adult control is only short term, because the source of the mosquito problem is not being managed. Adults will return as soon as new larvae and pupae mature.

For adult control, two basic application methods are space and residual treatments. Space treatments kill adults immediately, but only temporarily eliminate the problem. Space treatments are applied as fogs, mists, or fine sprays and they kill insects on contact. Residual insecticides may provide relief when applied to vegetation and trunks of trees or shrubs, or to walls of houses, where mosquitoes rest. Residual chemicals are contact poisons. They remain effective for several days, controlling insects that land on or crawl over treated surfaces during that time.

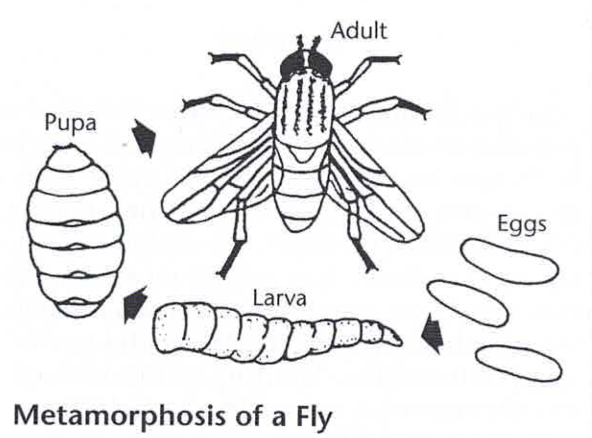
Fly Biology and Control

In addition to mosquitoes, several other groups of flies pose public health problems. Through sheer numbers, domestic nonbiting flies like flesh flies and blow flies can be a nuisance to people in their work, home, or recreational environment. Because flies are associated with human waste, they can become involved in **enteric** (intestinal) disease cycles. Besides being annoying, biting fly species like biting midges and no-see-ums may transmit pathogens that cause diseases such as tularemia. Many species of flesh flies deposit eggs or larvae on the flesh of living animals. These larvae invade the flesh of the host, producing a condition known as **myiasis**. Myiasis occurs commonly in some wild and domestic animals but infrequently in humans in Washington. This chapter discusses some of the major groups of other biting and non-biting flies that may require management.

All flies belong to the order Diptera, and have two distinguishing characteristics in the adult stage: 1) one pair of wings (or none), and 2) halteres, which are small knoblike structures located behind the wings.

Biologies

Flies undergo complete metamorphosis (egg, larva, pupa, and adult). A few species retain eggs within the body until they hatch and deposit larvae.



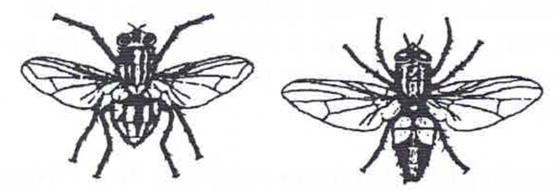
Metamorphosis of a Fly

Generally, the legless, wormlike larvae occupy a different habitat from the adult and also have different feeding habits. The time required to complete a life cycle varies with the species and depends upon a variety of environmental factors. Cool, moist spring weather limits domestic fly populations, except where larval habitats are either abundant or particularly temperatures are warm.

The following eight groups are of major importance to public health personnel in Washington. Other flies not listed here can also be of significant public health importance.

- house flies
- lesser house flies
- flesh flies
- bottle and blow flies
- stable flies
- biting midges, no-see-ums, or punkies
- black flies
- deer and horse flies

House Flies—*Musca domestica*. Commonly found in and around homes, the adult house fly does not bite. During the warm season, the house fly develops from egg to adult in 8 to 20 days, depending on environmental conditions. Larvae develop in many types of moist, warm, organic material, including manure and wet garbage. Adult flies feed on decaying organic material as well as milk and food intended for human consumption.

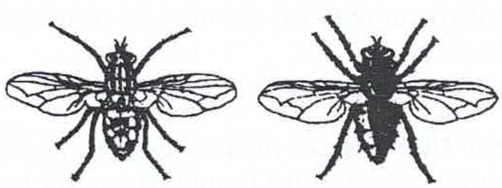


Musca domestica ***Fannia* spp.**

Adult flies usually are found within one mile of their larval habitat, although they are capable of dispersing over greater distances. Temperature, light, and humidity all affect fly activity. House flies can cause intestinal problems in humans by contaminating food with regurgitated bacteria.

Lesser House Flies—*Fannia* spp. Along with house flies, these flies are generally the most prevalent found in homes. Adult *Fannia* hover in midair in the center of a room or enclosure. The larvae live in decaying vegetable and animal matter, including human excrement, animal manure, and rotting grass piles. Larval development averages 7 days during the summer. *Fannia* larvae may contaminate food or cause myiasis in people.

Flesh Flies—Sarcophagidae. The adult flies of this large group normally do not enter homes. They look like oversized house flies. The larvae of most species live in animal tissue, insects, or manure, particularly dog feces. A few species cause myiasis in people and animals.



Bottle and Blow Flies—Calliphoridae. The adult flies of this widespread group enter homes, where they can be a nuisance, particularly in the fall. Adults have a shiny metallic appearance similar to colored glass—thus their common name. The larvae usually feed on animal tissue, especially carrion, but will infest fresh and decaying plant refuse when animal tissue is not available. The larvae of many species cause myiasis in animals and humans.

Stable Flies—*Stomoxys calcitrans.* This biting fly is found wherever people and their domestic animals occur, attacking both. Adults look like large house flies and are particularly bothersome just before a rain. Larvae are found in decomposing straw, hay, seaweed, or compost, but rarely in human excrement or animal manure. Larval development averages 3 to 4 weeks. Through their bite, adults can transmit some animal disease pathogens.

Biting Midges, No-See-Ums, or Punkies—*Culicoides* spp. *and Leptoconops* spp. These tiny biting gnats occasionally cause severe annoyance to people and animals. Only the females bite. Larvae live in aquatic or semi-aquatic situations, including moist soil. One species is a vector of **blue tongue** virus in cattle and sheep. Other species may be vectors of tularemia.

Black Flies—Simullidae. Only the females in this group are capable of taking a blood meal. The larvae and pupae cling to the rocks in the rapids of clear streams. In the Northwest this group occasionally causes severe annoyance to animals (rarely to humans) in the vicinity of fast-moving streams and sometimes irrigation canals. Through its bite, one species can vector the pathogen responsible for tularemia.

Deer and Horse Flies—Tabanidae. Like mosquitoes and black flies, only female tabanids feed on the blood of humans and animals. Their bite is painful. They deposit eggs in masses near water, allowing the larvae to mature in damp soil and litter. Through the bite of certain species of at least one genus, the tularemia pathogen can be transmitted.

Surveys

Conduct fly surveys to determine the relative population densities of the various fly species in an area. An understanding of the ecology of the various species, particularly their population dynamics, is essential to design correct survey procedures and control measures. Factors modifying population densities include reproductive capacity, mortality, and movement or migration. Limiting factors include the environment, competition, predation, parasitism, and disease.

Surveys for adult flies are generally more reliable than larval surveys due to the difficulty in locating fly larvae. However, it is still helpful to search for actual or potential larval media to narrow down the source of fly problems.

The most common survey methods used to determine species composition and population densities for flies include: fly traps in which adult flies are collected, counted, and identified; fly grills in which a standard slat grill is placed over natural attractants with the flies being counted and identified; fly reconnaissance surveys in which flies are caught and identified from natural resting places; and landing or biting counts taken in a given period of time. One or all of these methods are used to determine priority areas for control and to evaluate the effectiveness of control programs. Ordinarily a combination of fixed and random sampling stations are established in an area.

Management and Control

Sanitation

Good sanitation practices in urban areas will eliminate most nonbiting fly problems and should be the primary means for fly control. These practices range from the proper disposal of companion pet excrement to the correct storage, collection, and disposal of garbage and other wastes. The removal of weeds in urban areas helps eliminate resting places for adult flies.

Mechanical Barrier and Traps

Use of 16-mesh window screens will prevent most flies and mosquitoes from entering structures. In areas where smaller flies such as black flies (*Culicoides* spp.) are prevalent, a 23-mesh screen is necessary. Air screens or air curtains are used with varying success in commercial establishments to keep winged insects from entering while allowing free access for people.

Mosquito netting and clothing of tightly woven material provide some protection from mosquitoes and other biting flies.

Various fly traps are available that can be used indoors or out. An attractant is used and effectiveness depends on the species of flies.

Chemical Control

A wide variety of insecticides are available for the control of flies, either indoors or outdoors. Indoor applications include the use of space treatments, foggers, baits, traps, and pest strips. Use residual pesticides outdoors for extended control. The following are major types of registered insecticides:

- Botanicals and synthetic pyrethroids—classified as contact poisons but do not exhibit lengthy residual action: pyrethrum, allethrin, resmethrin, tetramethrin, phenothrin, fenvalerate (almost always used in combination with other active ingredients)
- Organophosphates—inhibit cholinesterase, resulting in overexcitation of the nervous system: malathion, temephos
- Carbamates—inhibit cholinesterase: methomyl
- Growth inhibitors—disrupt normal development and maturation of immature insects: methoprene

Remember that most insecticides can be hazardous to other organisms, particularly bees, fish, wildlife, and aquatic **invertebrates**. Exercise care when using insecticides in all locations. Pay close attention to the signal words and label precautions for personal and environmental safety and heed the protective equipment and first aid statements.

Cockroach Biology and Control

Cockroaches are one of the most disliked of all urban pests. Cockroaches eat human food and nonfood items or contaminate them with saliva, fecal droppings, or glandular secretions which impart a persistent musty odor to infested areas. Cockroaches are suspected of transmitting a variety of diseases, but are most often implicated in the transmission of *Salmonella*, the causal agent of food poisoning.

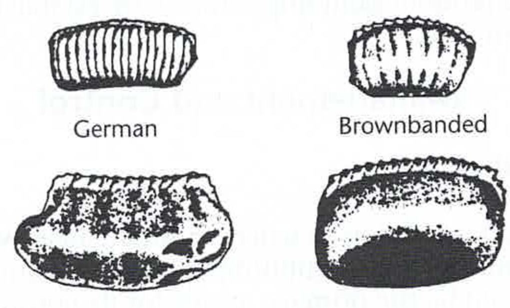
In Washington, four cockroach species may be encountered in homes, apartment complexes, or commercial establishments. These species differ enough that the control techniques used against one may not be effective against another. Because various combinations of these cockroaches may occur in a building at the same time, it is essential to accurately identify each species present before initiating any control measures.

Biology

Cockroaches grow and mature by simple metamorphosis. There are three stages in the life cycle of the cockroach: egg, nymph, and adult. Generations of cockroaches overlap, so all life stages may be found at any time of the year. Cockroaches typically require 6 months or more to fully mature.

All cockroaches common to Washington deposit their eggs in bean-shaped or purselike leathery egg cases called **oothecae**. These egg cases are dropped or attached to objects in out-of-the-way places by the females shortly after their formation. Cockroach egg cases are distinctive in shape and color and may be used to determine the species involved in an infestation.

Nymphs resemble adult cockroaches except that they are smaller, have undeveloped wings, and frequently are lighter in color. The nymphs may molt from 5 to 13 times before transforming into adults; the number of



Cockroach Egg Cases

Cockroach Identification and Habits

Species	Adult Identification	Adult Life Span	Egg Cases	Number of eggs
German *Blattella germanica*	0.5 inch long; pale brown; two dark brown lengthwise stripes on the shield behind the head; fully winged but rarely fly.	up to 12 months	slender egg case; 0.33 inch; light tan; female carries; case holds 30–48 eggs	384 eggs
Brownbanded *Supella longipalpa*	Males: wings cover abdomen. Can fly. Females: wings don't cover abdomen; can't fly.	3–11 months	light reddish brown; 0.25 inch; clusters; case holds 16 eggs	320 eggs
American *Periplaneta americana*	1.5 inches long, reddish brown to brown; light yellow/tan band around edge of shield behind the head; can fly but rarely do.	up to 15 months	dark brown; 0.33 inch; case holds 16 eggs	up to 1400 eggs
Oriental *Blatta orientalis*	Male: 1 inch long; wings cover 2/3 abdomen. Female: 1.25 inches long; broad abdomen, stubby wings. Neither sex fly or run quickly.	1–6 months	dark reddish brown, 0.5 inch; appear slightly inflated; case holds 16 eggs	up to 250 eggs

molts depends upon the species and localized environmental conditions.

Cockroaches are typically **nocturnal** insects appearing during the day only if disturbed or when there is an excessively large infestation. Cracks and crevices are their favored hiding and breeding areas.

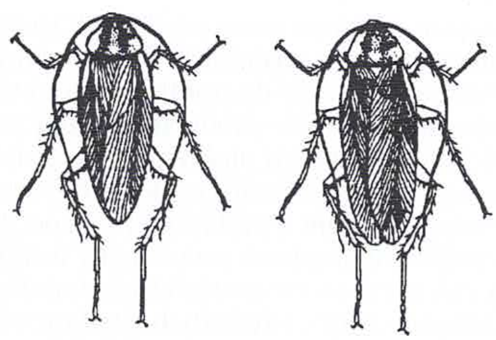
German cockroaches are the most common species found in Washington apartments, restaurants, hospitals, or other buildings in which food is stored, prepared, or served. The German cockroach produces more eggs and has more generations per year (three or four) than other cockroaches; thus, a large infestation can develop rapidly.

German cockroaches are often accidentally introduced into buildings with groceries (especially bagged potatoes and onions), beverage cartons and cases, and used furniture and appliances. Adults also may migrate between dwellings along plumbing or utility tunnels or between apartments in building complexes. Because of this tendency to migrate, check adjacent units for cockroaches. German cockroaches normally inhabit kitchens and bathrooms but also will occur in other rooms if infestations are heavy.

Brownbanded cockroaches are more apt to be found in private residences than in commercial buildings. Adults and immatures prefer to hide in warm, elevated areas near ceilings, behind wall decorations and loose wallpaper, in closets, beneath or inside upholstered furniture, and in electrical appliances (tv, stereo, toaster). These cockroaches fly readily and may infest any room in a dwelling. As a result, they often are more difficult to control than other cockroach species.

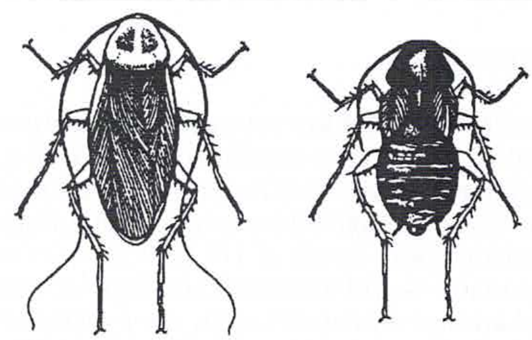
American cockroaches are much larger than German or brownbanded cockroaches. They are found in restaurants, supermarkets, and other commercial buildings where food is prepared or stored. They also may invade apartments or homes via sewer systems. Within a household, this cockroach prefers to live in cluttered basements on a wide variety of items (e.g., paper, sweets, hides, sewage seepage). When an infestation increases in size, individuals may spread to the kitchen, bathroom, and other rooms.

Oriental cockroaches are relatively large, but can be distinguished from the other species because of their dark mahogany to black color with short wing covers. They do not readily fly. They feed on a wide range of decaying organic matter. Outdoors, these insects are found in cool, moist habitats such as beneath decomposing leaves or stones and in garden mulching materials, trash and garbage piles, and municipal sewer systems. Occasionally, during unseasonably cool periods or with the onset of fall weather, there may be a mass movement of Oriental cockroaches into buildings. These cockroaches invade human structures through sewer drain pipes, founda-



German Cockroach

Brownbanded Cockroach



American Cockroach

Oriental Cockroach

tion cracks, ventilators, and poor-fitting doors. Normally this species is not abundant in buildings. Nevertheless, populations can become very large, especially in moist areas such as basements, near drains or leaky water pipes, and beneath refrigerators, sinks, and washing machines.

Surveys

It is important to evaluate a cockroach infestation by properly identifying the species present and population size and composition. Trapping is an effective way to determine infestation severity, detect cockroach population increases, and monitor the effectiveness of control measures. Several types of cockroach traps are available. Use bait traps with a highly attractive food source such as stale beer, soft drink, or molded bread.

A second survey approach is based on the nocturnal behavior of cockroaches. Turn on a light during a dark period to monitor the presence of cockroaches. If you see any cockroaches, there is a relatively large infestation.

Another method uses insecticides. Spray a low concentration of pyrethrin or synthetic pyrethroid. This will flush the cockroaches out of hiding to allow an estimate of their numbers.

Management and Control

Cockroach infestations usually are most successfully reduced by a combination of prevention, sanitation, and chemical control.

Prevention

Prevention is the key to successful cockroach control. Preventive measures will minimize cockroach invasion of buildings. These insects can be discouraged from entering buildings by sealing any cracks of 1/8 inch or more in foundations and exterior walls. Examine the seal around air conditioners, doors, windows, and other structural openings to insure there are no gaps that permit cockroach entry. Store refuse in durable, securely covered containers away from buildings. Inspect incoming merchandise such as beverage cartons, groceries, dry cleaning, luggage, and used appliances or furniture for hitchhiking cockroaches or their egg cases.

Inside a dwelling, eliminate all cockroach hiding areas and food sources. Repair cracks and holes in floors, walls, and ceilings. Seal openings around plumbing fixtures, furnace flues, electrical outlets, between window sills and walls, and along baseboards or ceiling moldings. Repair leaky water faucets and pipes.

Sanitation

Sanitation or cleanup will aid considerably in cockroach control. Do not leave unwashed dishes, kitchen utensils, and exposed food products overnight. Clean up all spilled food, liquids, and water. Clean off grease film on appliances regularly. Clean areas beneath cabinets, furniture, sinks, stoves, and refrigerators often, as well as cupboards, pantry shelves, and storage bins where minute amounts of food frequently accumulate. Keep kitchen waste and dry pet food in cockroach-proof containers such as those with tightly-fitted lids or other closures. Improperly stored dry pet food is one of the most frequent sources of food-pest buildup. If pets are fed indoors, do not allow unconsumed food to remain in the feeding dish overnight. Dispose of accumulated stored papers, boxes, and other nonessential items that provide excellent hiding and breeding sites for cockroaches.

Sanitation problems often are difficult to solve when caused by a customer, tenant, or homeowner. Some people do not understand the relationship between moderate to poor sanitation and cockroach problems. Others have developed a tolerance for cockroaches and do not consider them a problem. If this occurs in an apartment complex, one heavily infested unit can serve as the source of reinfestation for adjacent units. Often such a tenant will not complain about cockroaches, and no one else knows where the problem originated.

Chemical Control

After sanitation practices have been implemented, chemical control tactics can be implemented. While treating with chemicals, be diligent in continuing sanitation practices. Read all pesticide labels carefully for use restrictions and precautions. Human and pet exposure are significant concerns.

One insecticide treatment rarely results in total control of cockroaches. Base the frequency of retreatment on sanitation practices, thoroughness of insecticide application, and how vulnerable the structure is to reinfestation by cockroaches.

The type of insecticide and application method used should depend on the location and nature of the infestation. Target treatments in areas where cockroaches hide during the day or regularly travel at night. Familiarize yourself with the favored hiding areas of the different cockroach species described above.

Baits are highly effective and recommended. They greatly reduce pesticide exposures to humans and pets. They are available in granular formulations, plastic **bait stations**, and gel formulations in syringes. Use products that target the correct species of cockroach (type and size). Place gels in cracks and crevices, but not in food areas. Make sure they are inaccessible to pets and children.

Dusts need to be applied as a thin film and can be used under refrigerators, stoves, sinks, and in wall voids and cracks and crevices. Do not apply on shelves or in drawers where food is kept.

Sprays are used as an initial clean out treatment intended to provide immediate reduction of the problem. In occupied structures, pesticide labeling requires tenants or managers to prepare for a treatment by removing all items from kitchen and bathroom cabinets, closets, and counter tops; followed by a general cleaning.

Foggers should not be used for managing cockroaches.

After treatment is complete, surfaces are dry, and the reentry period has lapsed, wash eating surfaces.

If you are experiencing chronic cockroach complaints, yet none of the units you are treating are severely infested, a problem unit likely exists in the building complex. A routine inspection of all the units in an infested area often will reveal the origin of the problem. Also, beware that insecticide resistance is not uncommon in cockroaches.

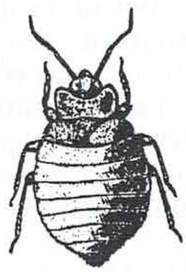
Several insecticides are registered in Washington for cockroach control. Some registered insecticides include:

- Botanicals and synthetic pyrethroids—classified as contact poisons but without lengthy residual action: bifenthrin, cypermethrin, esfenvalerate, permethrin, phenothrin, pyrethrin (almost always used in combination with other active ingredients)
- Organophosphates—inhibit cholinesterase, resulting in overexcitation of the nervous system: acephate, malathion, temephos
- Growth inhibitors—disrupt normal development and maturation of immature insects: hydroprene
- Other: boric acid, hydramethylnon, indoxacarb, silica gel

Remember, if cockroaches are deprived of **harborage**, food, and water they cannot survive for long. Few homes exist which do not provide a little of both. Most serious cockroach problems occur where harborage is extensive and sanitation is poor.

Bed Bug Biology and Control

The United States is experiencing an alarming resurgence of bed bugs. Despite the name, these insects are commonly found throughout homes, apartments, hotels, motels, health care facilities, dormitories, shelters, schools, cruise ships, buses, and trains. Bed bugs are also showing up in clothing stores, movie theaters, laundries/dry cleaners, furniture rental outlets, and office buildings.



Bed Bug

Bed bugs (*Cimex lectularis*) are blood-sucking **ectoparasites** of significant public health importance because they feed on the blood of sleeping people; however, they are not known to transmit disease. When bed bugs bite, they inject an anesthetic that prevents a person from feeling the bite and an anticoagulant that prevents the blood from clotting the bite site. Because bites usually occur while people are sleeping, most people do not realize they have been bitten until marks appear (up to a week or more later). The bite marks are similar to that of a mosquito or a flea—slightly swollen and red areas that may be random or in a straight line. Because bed bug bites often itch, they can lead to insomnia, anxiety, skin problems, and secondary infections that arise from profuse scratching of the bites. A secondary health concern is the possibility of people misusing pesticides that are not intended for indoor residential use, which puts all dwellers and visitors at risk of exposure.

The economic consequences of a bed bug infestation are significant due to the costs associated with inspections and control measures. The ability of bed bugs to travel between rooms and housing units adds additional costs and complexities for coordinating control measures and encouraging participation from multiple residents. Pesticide resistance and limited control choices make treatment even more difficult. Some bed bug populations are resistant to almost all pesticides registered to treat them.

Everyone is at risk for bed bugs bites when visiting an infested area. In addition, anyone who travels frequently or shares living and sleeping quarters where other people have previously slept has an increased risk for being bitten and spreading bed bug infestations. When you inspect or treat a facility, home, or other location, make sure you do not transfer bed bugs into your car or home.

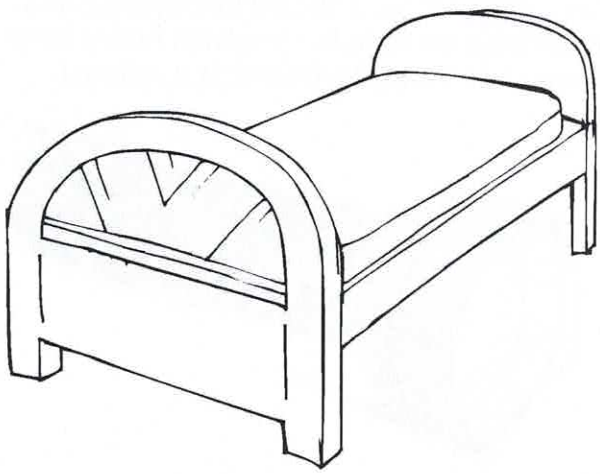
Biology

Bed bugs are small (ranging in size from poppy seeds to apple seeds; adults are 3/16th inch long), flat, oval, reddish-brown in color, and wingless. They undergo gradual metamorphosis with egg, nymph, and adult stages. Under favorable conditions (70–80°F), they can complete development in as little as a month, producing three or more generations per year. Entomologists estimate bed bugs feed weekly and prefer human hosts, but will feed on family pets. They can survive over a year without a blood meal, but need to feed between each molt, and will crawl in search of a new host if none are available nearby.

Many nest-dwelling animals have their own type of bed bug, including bats and pigeons. Bat bugs are very similar in appearance to bed bugs, so the two are often confused. Bat bugs will feed on people if a home bat infestation is removed.

Surveys

The only way to confirm a bed bug infestation is to identify the insects alive. Bite marks that appear on people's trunks, legs, or arms are clues that bed bugs are present, but since this type of evidence may take as long as a few weeks to develop in some people, it is important to look for other indications to determine if bed bugs have infested an area.



Bed bug signs include live bed bugs of all sizes, their exoskeletons (shed skin) after molting, and rusty-colored spots from their blood-filled fecal material. Look for these signs in mattress seams, on bed sheets or nearby furniture, and along baseboards. Infestations may give off a sweet, musty odor as well.

Habitat

Bed bugs are most commonly found close to where people sleep or spend a significant period of time during the night. The pests' small flat bodies allow them to fit into the smallest of spaces and stay hidden during the day. Although they can travel over 100 feet in one night, they tend to live within 5 to 20 feet of where people sleep.

Hiding Places

Seams of mattresses	Edges of carpets
Box springs	Walls
Bed frames	Ceilings
Headboards	Moldings
Dresser tables	Alarm clocks
Cracks or crevices	Under any clutter
Behind wallpaper	Light fixtures
Remote controls	Heating/cooling vents and ducts
Spaces within and along floor boards	

Movement and Transport

Bed bugs readily move to a new room or floor by crawling or hitchhiking on a person or object when their population increases. Bed bugs are also transported from place to place as people travel. Most people don't realize how easy it is for stow-away bed bugs to hide in the seams and folds of luggage, overnight bags, folded clothes, bedding, and furniture, potentially infesting new areas as these items are relocated.

Management and Control

Controlling bed bugs is a time and money-consuming activity. However, bed bugs can be eliminated with a coordinated effort that includes cooperation from all affected parties: resident(s), the building manager (in multi-family housing), and a pest management professional. There is no single tool or activity that will eliminate bed bugs, including pesticides. Multiple techniques are always required because bed bugs are small, good at hiding, and live without feeding for up to a year. In some cases, bed bugs are resistant to the pesticides used against them, meaning that many will survive treatment. The reduction of household clutter is absolutely necessary for fighting bed bugs. Despite the challenges, the technology of bed bug control is improving and becoming better understood. Treatment of a living area should focus on containment of the infestation.

IPM for Bed Bugs

- Encourage tenants and/or guests to report bed bugs (unreported and uncontrolled bed bugs will spread quickly) and keep records of such complaints.
- Respond quickly to complaints with an inspection and intervention.
- Develop an aggressive bed bug control protocol with multiple treatment strategies.
- Raise tenant and/or guest awareness about bed bugs.
- Institute a prevention program centered on awareness.

Reporting and Recordkeeping

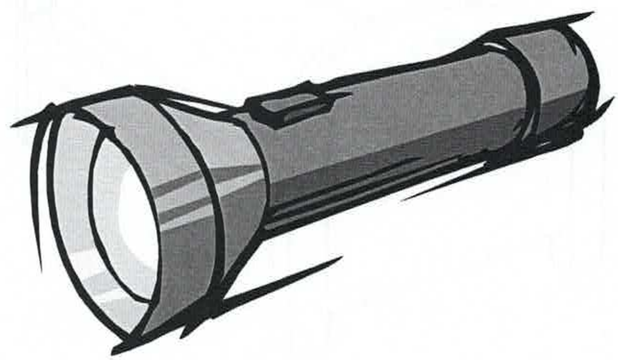
It is critical for managers of multiple-unit housing to encourage residents to report suspected cases of bed bugs because if the presence of these pests is not addressed immediately, the population will grow quickly and spread throughout the facility. Eliminating a widespread problem is much more expensive and difficult than a limited one. At a minimum, the following information should be recorded:

- Date of the complaint
- Type of complaint (bites, bug sightings, damage to property)
- Unit or room number associated with complaint
- Date of first pest inspection
- Results of the inspection (what and how much was found)
- Dates of pest management activities
- What pest management strategies were used, such as cleaning, pesticide treatments, and resident education

Inspection

Determine the extent of the infestation. Adult bed bugs can hide in any space as thin as a piece of paper. Young bed bugs are even smaller. When conducting an inspection, move slowly and avoid disturbing hiding bugs so they don't scatter. Prioritize the risk of infestation by checking the area 5–20 feet around where people sleep or sit, which is the typical distance a bed bug travels. Keep in mind that in a low-level infestation, the bed bugs will be concentrated close to sleeping areas. Bed bugs may turn up in unexpected places in moderate and high-level infestations. If the infestation is large, carefully inspect every object (toys, jewelry boxes, phones, etc.) in the affected area.

It is important to realize that a bed bug infestation in a living area (bedroom, living room, apartment, dormitory room, shelter room or unit) might spread to adjacent units or those below, above, or to the sides. This is especially true if the bed bug population is large or if pesticides are used in the original unit. Adjacent units should be inspected and if bed bugs are found or residents notice bites, these areas should be treated as if infested.



Inspect mattresses. Look along the top and bottom seams, along each side of the piping material sewn onto the edges, under mattress handles and buttons, along or inside air holes, between the mattress and box spring, along the platform or frame, and inside material folds. Use alcohol or baby wipes to rub suspected bed bug droppings. If the spots dissolve into a reddish-brown color, this indicates bed bug droppings; continue inspecting until you find a live bed bug.

Inspect box springs. Look at all the points where the box spring sits on the bed frame. Be careful to lift slowly to avoid scattering bed bugs. Check the top surface of the box spring, inside folds of material, along seams, and where the material is tacked to the frame. Turn over the box spring and remove the thin cloth on the underside. Use a flashlight, a hand lens, and a crevice tool to check the spaces between the box spring frame parts. Look around and beneath furniture staples and tacks. Use a flushing agent such as compressed air to chase bed bugs out of hiding spots. Place double-sided tape or carpet tape on the underside of furniture to monitor for wandering bed bugs.

Inspection Tools

- Magnifying glass
- Strong flashlight
- Plastic self-closing bags for collecting specimens
- A crevice tool (putty knife, playing card)
- Compressed air for flushing bed bugs from cracks and crevices
- Hot air dryer with airflow on low setting
- Tools for removing light switch, electrical plates, and disassembling furniture
- Glass-cleaning or baby wipes to check for bed bug fecal material stains
- Cotton swabs for checking stains in crevices
- Sticky traps placed under beds and checked regularly

Inspect bed frames and headboards. Bed bugs prefer wood beds and headboards over metal bed frames; however, they do hide in metal and plastic crevices and where mattresses touch metal frames. Visually inspect and use a crevice tool in all joints of the frame where parts meet. Turn the frame over and inspect from the underside. Check screw and nail holes for bed bugs. Remove the headboard and look along the joints and on the wall behind it.

Inspect other furniture and items. Empty the drawers and shelves of the furniture closest to the bed. Place items into plastic bags to be inspected and cleaned or heat-treated. Examine every corner and the undersides of drawers, using the crevice tool to check under the metal drawer guides. Inspect gaps wherever the crevice tool will fit, such as between shelves and bookcase frames. Turn over all furniture and remove the thin cloth backing to inspect under each piece. Check where fabric attaches to frames, especially stapled areas. Look inside at all wood parts of the frame and any screw or nail holes. Place electronics such as lamps, remote controls, alarm clocks, and radios in a plastic bag for further inspection. Inspect pillows and cushions, particularly the seams and folds around zippers. Look at and under the legs of chairs and couches.

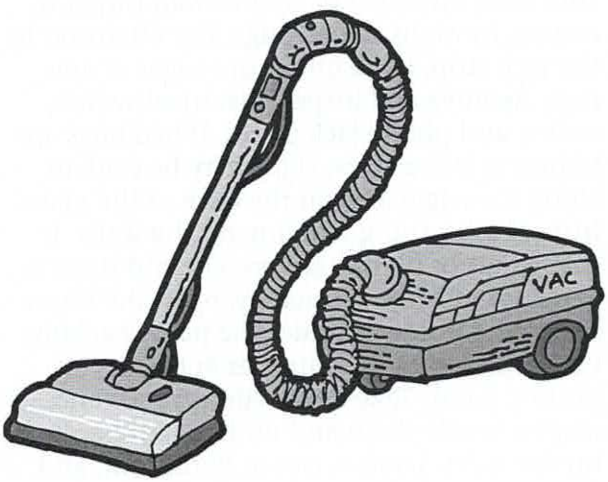
Inspect room perimeters. Look at moldings or the joint between the floor and wall closest to the bed. Use the crevice tool to check behind moldings. The tool will chase bed bugs out of hiding if used in a sweeping upward motion. Fold back the edges of wall-to-wall carpet to inspect for signs of bed bugs. Pay attention to the tack strip. Look under the edges of area rugs. Remove and inspect electrical switch, outlet, and phone jack plates. If bed bugs are hiding in these areas, signs may be evident along the edges and on the back of the plate. Inspect everything hanging on the walls. If framed art or photos are present and there is evidence of bed bugs nearby, open the frame to inspect inside or under the paper backing. Check under loose wallpaper and areas of peeling paint. Take down curtain rods and inspect inside them and underneath hardware on the walls. Look at closet, bathroom, and other door frames, along hinges, and in the bore hole for the latch on each door. If bed bugs are on walls, you may find more under ceiling moldings and in smoke detectors.

Control Strategies

For the reasons described above, bed bug control is quite complex, and therefore relies on using many different coordinated strategies over a period of time to achieve success. Some of the more common steps used in combination for bed bug control are listed below.

- Clean and organize the bed, bedroom, other living areas, furniture, and other belongings, including elimination of clutter.
    - Bag items and garments for laundering.

- Remove belongings from premises if not infested and place them in storage during treatment.
  - Check items again prior to returning them.
- Wipe off dead bed bugs, blood stains, eggs, and droppings with hot, soapy water.
- Use a commercial steamer so appropriate temperatures can be reached (160–180°F).
- Physically remove bed bugs and eggs using a vacuum.
  - Do not vacuum until after steaming is complete; otherwise, you risk infesting the vacuum.



- Use heat or cold treatments to kill all life stages.
  - Wash all items showing bed bug stains in hot water (140°F).
  - Launder garments and other items (120°F minimum).
  - Dry on the highest setting for at least 30 minutes.
  - Seal pest-free items in a plastic bag until bed bugs are eliminated.
- Use mattress encasements, interceptors, or sticky traps as barriers for control or monitoring.
- Eliminate bed bug hiding spots.
  - Fix peeling wallpaper and paint.
  - Caulk or seal cracks and crevices around the room and on furniture.
  - Seal floors or the spaces between floor boards or tiles.
  - Make other repairs to the living area to reduce hiding spots.
- Use chemicals.
  - Select and use only pesticides effective against bed bugs and labeled for indoor use.
  - Consider hiring a pest management professional.
- Prevent reinfestation.
  - Vacuum daily and seal/dispose of bag in an outdoor trash receptacle after each use.
  - Check mattress covers regularly for tears. Seal up tears with tape.

Properly applied steam treatments kill all life stages of bed bugs, including the eggs, which are protected from the effects of most pesticides. Steam can be used on mattresses and plush furniture, such as couches and chairs. However, steam only kills bed bugs in places where the steam can reach. Dry steam or low vapor steamers are better because they use and leave behind less moisture.

It is critical to steam clean before vacuuming for several reasons. Steam flushes bed bugs from their hiding spots to be killed or vacuumed. Reducing the number of live bed bugs vacuumed up reduces the chance that the vacuum becomes infested and spreads bed bugs to new areas. See the Bed Bug Handbook by Pinto et al. for additional details on using steam.

The use of cold or freezing temperatures to kill bed bugs is sometimes recommended, although this method varies in effectiveness. Placing household items such as books into a freezer may kill some bed bugs, but reports indicate that some bed bugs can recover from being frozen. Items treated in this way must be stored in a freezer for at least 2 weeks.

Only a few types of pesticides are available for use against bed bugs. They come in different formulations (liquid, **aerosol**, dust, and gas), but most have a similar mode of action. Some low-risk products are available. Consult a pest management professional for information about treatment choices. Several types of pesticides that are commonly used for the control of bed bugs include:

- Liquid insecticide for treatment of moldings, carpet edges, cracks, and crevices.
- Aerosol insecticides for treating bed frames, box springs, furniture, cracks, and crevices.
- Dusts (that may or may not include an insecticide compound) used in cracks and crevices, inside walls, and behind electrical outlet covers and switch plates.
- Fumigants (gases) for treating whole buildings or the contents of a home. Fumigants are different from total release foggers.

Ineffective Strategies

Simply abandoning rooms or even a whole facility is not a guarantee that bed bugs will disappear. Also, discarding beds and bedding will not solve the problem since they live in other areas of infested rooms. Bug bombs or total release foggers are not advised since they do not penetrate the cracks and crevices where bed bugs hide. Total release foggers are ineffective and may cause bed bugs to move into adjacent housing units.

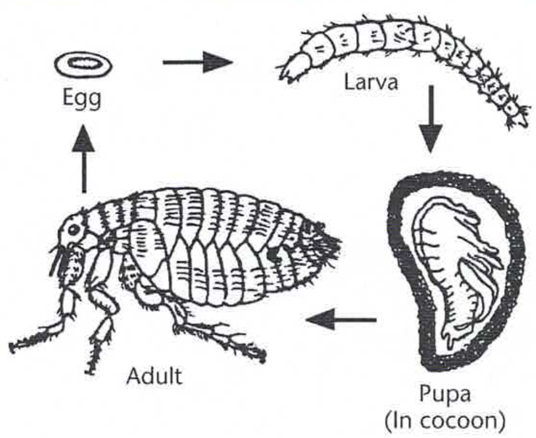
Other Arthropod Biology and Control

Additional species of human heath concern in Washington include other insects (e.g., fleas, lice, and wasps) and non-insect arthropods (e.g., (ticks, mites, and spiders). Public health issues consist of simple nuisance, **dermatitis**, disease, and deadly allergic reactions.

Fleas

Fleas are small, dark brown, wingless insects that appear to be flattened sideways (laterally compressed). Adult fleas are ectoparasites of warm-blooded **vertebrate** animals. Their bites cause severe annoyance to people and pets. They move by crawling and jumping. The majority of the species infest small mammals, especially rodents. Many show a degree of host specificity; a few are found on a variety of hosts.

Fleas undergo complete metamorphosis. The life cycle varies with environmental factors and may be completed in as few as 2 weeks to as long as a year or more. Females oviposit on the host and the eggs soon drop into the nesting material, or they deposit eggs directly onto host nesting material. The wormlike larvae feed on **detritus** that occurs in nests or in animal quarters. Pupae and pre-emergent adults can survive many months inside a silken cocoon.



Life Cycle of the Flea

Emerged adult fleas survive less than 2 weeks. Adults have sucking mouthparts and larvae have chewing mouthparts.

Common and important flea species in Washington include the cat and dog flea, the human flea, and the northern rat flea. Cat and dog fleas feed on people, dogs, cats, rats, raccoons, and foxes and are found commonly in and under homes or other habitats their hosts frequent. Cat fleas are the more prevalent of the two. Both fleas readily attack people, usually causing problems during the summer and fall months when flea populations reach high densities. Larvae are commonly found indoors on rugs and furniture. Problems with fleas frequently increase for people when pets are removed from premises because the preferred host is no longer available.

The human flea is found in Washington. Its bite can cause **dermatitis**. Besides feeding on humans, human fleas attack a wide variety of hosts, including deer, swine, dogs, and ground squirrels.

The northern rat flea is the species most often found on domestic rats and mice in Washington. It does not readily feed on people.

Some flea species transmit pathogens to humans via pets. For example, dog fleas serve as an alternate host for dog tapeworm. Washington has four flea species that infest **sylvan** (wood or forest) rodents and can transmit the plague organism from animal to animal and from animals to humans. Thus, they play a role in maintaining a low level of plague in wild rodent populations in Washington.

To determine the densities and species composition of wild rodent-flea populations, trap and deflea host animals, inspect nesting material for fleas, and flag animal burrows by dragging a piece of flannel material over the burrow surface. Hungry fleas will respond by attaching to the flannel. Identify flea species and determine the level of concern their population poses to humans.

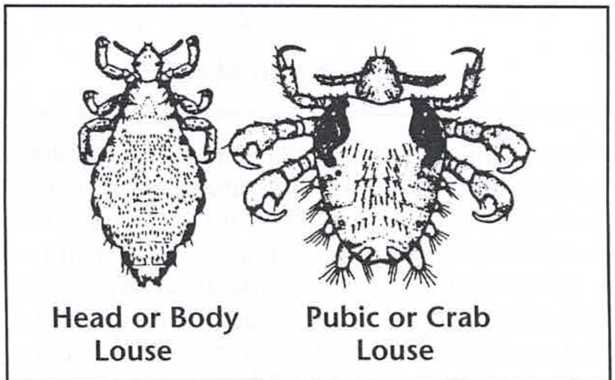
Flea combs and systemic medications can effectively control fleas on pets. Combing may not be practical since it must be very thorough to be effective. Many of the systemic medications are growth regulators that stop immature fleas from becoming adults. Flea treatments for pets are available through veterinarians, pet stores, and hardware chain stores. Be sure to consult a veterinarian for application procedures.

Control fleas in the home by thorough and repeated vacuum cleaning of carpets, floors, upholstered furniture, and dog boxes, and by regular airing and laundering of pet bedding. If necessary, use an insecticide registered for use indoors against fleas. Treat fleas in yards and dog kennels with insecticides registered for outdoor use against fleas. Raking and disposal of lawn debris will decrease outdoor flea larval infestations.

Lice

Two species of lice belonging to the insect order Anoplura infest humans: head or body louse (*Pediculus humanus*) and pubic or crab louse (*Phthirus pubis*).

Lice that infest humans are small, grayish-white ectoparasites. They spend their entire life cycle on their host except for the body louse, which stays in the seams of clothing



when it is not feeding. This characteristic of the body louse creates the potential for widespread infestations under unsanitary conditions. Head lice may be spread by the shared use of items used or worn on the head. The crab or pubic louse is transmitted primarily through intimate personal contact. Positive identification of lice or their eggs is imperative before initiating control. Lice undergo simple metamorphosis with three stages in their life history: egg, nymph, and adult. They possess piercing, sucking mouth parts used to obtain blood meals from their hosts.

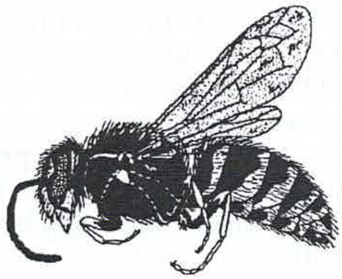
Lice management requires close, frequent personal attention and rigorous hygiene. Commercially prepared remedies are available for elimination of lice. Consult a physician if infestation persists.

Head and body lice can survive away from a host for a few days. Reinfestation can occur from surfaces of furniture and clothes. Vacuum furniture and dry heat or freeze clothes to remove lice infestations.

Stinging Insects

Yellowjackets, wasps, mud daubers, and bees are all stinging insects that may injure people. Their sting normally causes pain and a reddened welt, but occasionally causes severe allergic reactions and even death. These insects become problems when they nest near or in dwellings or other places frequented by people. They nest in trees, in the ground, under eaves, or in walls depending on the species. Yellowjackets usually cause the most problems of the stinging insect pests in Washington.

Yellowjackets undergo complete metamorphosis. In Washington, the queen constructs a new nest each spring. Her workers continue to build the nest and forage as she lays eggs, thus increasing the colony size over the summer. Populations usually peak near the end of summer. Yellowjackets do not reuse their abandoned nests the following year. The mated queens overwinter in cracks and crevic-



Common Yellowjacket
(Vespula vulgaris)

es (especially in wood piles and siding). Some yellowjacket species are particularly pestiferous because they are attracted to meat and fruit. They can become very bothersome at picnics and outdoor barbecues. To avoid being stung, do not panic, swat, or run. Let the wasp land on you, find nothing of interest, and leave on its own.

Traps are available to reduce some yellowjacket species populations. Good sanitation practices, such as the use of containers with tight-fitting lids, will reduce the numbers of foragers around garbage cans.

For more permanent control of yellowjackets, insecticides may be necessary. Treat the entire nest for full control. Treat nests early in the season, before peak numbers of yellowjackets are present. Treat after dark, when the insects are inactive and in the nest. Take care if using flashlights because yellowjackets may be aroused by the light and leave the nest. Wear appropriate protective clothing. Insecticides registered for control of wasps include:

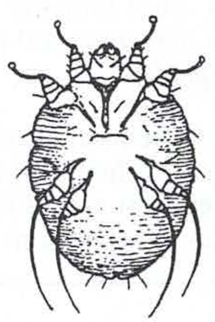
- Botanicals and synthetic pyrethroids—classified as contact poisons but without lengthy residual action: pyrethrum, allethrin, resmethrin, tetramethrin, phenothrin, fenvalerate (almost always used in combination with other active ingredients)
- Organophosphates—inhibit cholinesterase, resulting in overexcitation of the nervous system: malathion
- Carbamates—inhibit cholinesterase: propoxur, bendiocarb, carbaryl

Beekeepers may be of assistance in the removal of honey bees, bee swarms, or nests.

Mites

Mites belong to the arthropod group Arachnida, so are more closely related to spiders than insects. Mites of public health importance can be divided into two general groups: 1) those that parasitize humans and 2) those that normally parasitize birds or mammals other than humans, but which may occasionally bite humans.

The most important mite parasitizing people is the human itch mite, *Sarcoptes scabiei hominis*, which causes **scabies**. Human itch mites cause intense itching when the mites are stimulated by warmth. They make tunnels just under the skin that appear as reddened streaks. Scabies can be confused with other conditions, so suspected cases should be confirmed by a physician. Confirmed cases require medical treatment. Mites are primarily transmitted by direct personal contact and rarely through bedding, clothing, towels, etc. Clothing and like items can be disinfected by laundering with hot water, dry cleaning, or freezing.

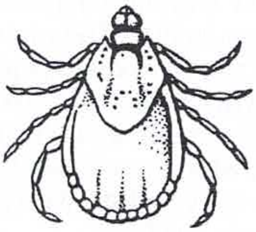


Human Itch Mite

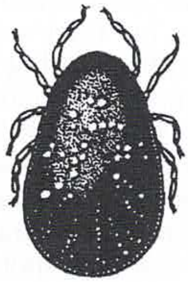
Various mites that normally parasitize rodents or birds may occasionally invade homes. Such invasions are most likely when the preferred hosts have been removed, as occurs during rodent control efforts. Tropical rat mite bites are irritating and occasionally cause painful dermatitis. Northern fowl mite and chicken mite bites cause itching. Mouse mite bites can transmit disease to humans. These mites are best controlled by removing the source host. This may involve trapping rodents and destroying bird nests.

Ticks

Ticks are arachnids and resemble oversized mites. Their bodies are oval, flat (when unfed), hard, and leathery. Adults have 8 legs and larvae have 6 legs. Ticks feed exclusively on the blood of various animals, including humans. When fully engorged, females can expand to 1/2 inch in length. Many tick species require progressively larger host species during their life cycles (e.g., rodents, then rabbits, then deer). Ticks are divided into two main groups: hard ticks (family Ixodidae) and soft ticks (family Argasidae). Hard ticks possess a **dorsal** shield or scutum, which distinguishes them from soft ticks that lack this structure.



Hard Tick



Soft Tick

Hard Ticks can be problematic for humans through disease transmission and discomfort caused by their bites. *Ixodes* spp. are considered the principal vectors of Lyme disease. *Dermacentor andersoni* (Rocky Mountain wood tick) and *Dermacentor variabilis* (American dog tick) are known to transmit **Colorado tick fever**, Rocky Mountain spotted fever, and tularemia. *Rhipicephalus sanguineus* (brown dog tick) is primarily a pest on dogs and rarely bites humans; however, it can transmit Rocky Mountain spotted fever.

Hard ticks are present from March to August in a variety of outdoor habitats. They rest on grasses and low vegetation where they attach themselves to animals or people that brush against the plants.

The life cycles of these species are similar. The female takes a blood meal while remaining attached to the host for several days. She then drops from the host and deposits several thousand eggs on the ground, few of which survive to adults. The 6-legged larvae hatch within a couple of weeks and locate a small animal host, usually a rodent or lizard. After obtaining a blood meal the larvae drop from the host, molt, and emerge as 8-legged nymphs. The nymphs repeat the process of feeding and molting until they become adult ticks. The adult ticks of both sexes require larger animals or humans as hosts. Their life cycle usually requires 1–2 years to complete. These species are most abundant in brushy areas along trails, stream beds, and abandoned log roads where there are breaks in the habitat. Temperature and humidity play a significant role in tick development and activity.

Soft Ticks primarily feed on birds and small mammals, which act as their preferred hosts. At least one species of soft tick in Washington, *Ornithodoros hermsi*, is known to be the vector of **tick-borne relapsing fever**. These ticks feed frequently, but only briefly. They are primarily nocturnal, and usually found in the nests of their hosts.

Female soft ticks lay several small clutches of eggs and need a blood meal before oviposition. In some species the larvae molt to the nymphal stage without feeding. Five to six nymphal molts occur before ticks reach the adult stage.

People are most likely to come in contact with soft ticks when occupying cabins or buildings where small mammals have their nests or when camping in the immediate vicinity of rodent burrows, nests, or deer bedding areas. Take caution when choosing sleeping quarters in old cabins or buildings where pack rats and other rodents are, or have been, present.

Surveys

Wood ticks that create problems for people can be collected by "flagging" in usual tick habitat. The ticks attach themselves to a piece of white flannel cloth as it is dragged over low vegetation. By collecting from a designated distance or area and identifying the ticks collected, surveyors can determine species composition, relative population densities, and seasonal and annual fluctuations. Some soft tick species are collected by using a carbon dioxide attractant trap or by examining animal nesting material.

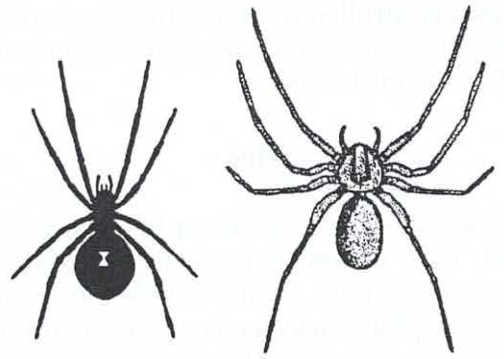
Control measures should be targeted at individuals or locations where population levels threaten human health.

- **Personal:** Wear clothing made from tightly woven material. Tuck trousers into socks and boots and shirt into trousers. Use repellent on exposed body surfaces and on clothing. Check clothing and body twice daily and remove any ticks found.
- **Host and General Area:** Remove brush and high vegetation overhanging hiking trails and in and around camp sites. Treat infested areas with pesticides labeled for tick control. Follow label instructions.

Spiders

All spiders are beneficial arthropods. They feed on insects and other arthropods. In Washington, some spiders occasionally bite humans, causing severe reactions. All spiders have a toxin that is injected when they bite, which is how they subdue and ingest their prey. The reaction to spider bites varies dramatically among individuals. Most people experience slight pain at the site where bitten, but those who are sensitive to spider toxins may require medical treatment.

The black widow spider lives in Washington and can cause human health problems. Bites usually result from accidentally squeezing a spider when picking up an object to which it is clinging. Bites may occur when putting on clothing or shoes in which the spider is hiding. The brown recluse (or fiddleback) spider does not reside in Washington, but may be transported in luggage, cars, etc. from places where it is found (Midwest and South).



Black widow spiders, *Lactrodectus mactans*, are the most poisonous spider in the United States, but there are few authentic records of deaths resulting from its bite. The mature female spider is easily recognized by its jet-black, globular body with a red hourglass mark on the underside of the abdomen. The males and immatures, which are smaller than the females, generally have yellow, white, and red bands and spots over the back.

Black widows spin irregular-shaped webs of coarse silk in dark places usually near the ground. Trash, rubble piles, and littered areas are favored by these spiders, but outbuildings and other structures may also be infested.

This spider is shy and retiring, and the mature male does not feed or bite. Female black widow spider bites cause severe abdominal pain felt almost immediately, and the intensity increases with time.

Hobo spiders, *Tegenaria agrestis*, belong to the group of funnel-web or funnel weaver spiders. This species builds funnel-shaped webs in dark, moist areas, often in basements, and sits in the mouth of the funnel waiting for prey. The funnel opens at both ends, and the web expands outward into a broad, slightly curved sheet.

The head and bodies of these spiders are relatively large: female—7/16 to 10/16 inch; male—5/16 to 7/16. Their colors are a drab, mottled brown. They have long legs and are swift runners that travel fairly long distances, especially at night.

Most spiders can bite and since all spiders produce venom it is possible to have a negative reaction to a spider bite. Be sure to bring the spider to an expert for correct identification. If you are suspicious of a chronic, open sore, have a physician look at it and treat the symptoms.

Probably the best management strategy for spiders is to be aware of and alert for the ones that can cause problems. To prevent spiders from entering a home, seal cracks and crevices. If they are found in homes, vacuum them up and dispose of the vacuum bag. Sweeping and stabbing them with a straw broom also is effective. Good housekeeping will reduce habitat for spiders to invade. Use pesticides only as a last resort. Chemical control will be temporary because more spiders will invade unless preventive measures are taken.

Rodent Biology and Control

Rodents are a large group of mammals characterized by two continously-growing sharp incisors they use to gnaw wood, break into packaged food, and bite predators. Some rodents are characterized as pests because they 1) contaminate products, 2) damage home supplies and structures, or 3) spread diseases such as tick-borne relapsing fever, Colorado tick fever, Rocky Mountain spotted fever, tularemia, and plague. They can also cause fires by gnawing the insulation from electrical wiring.

Three species of urban rodents, *Mus musculus* (house mouse), *Rattus norvegicus* (Norway rat), and *Rattus rattus* (roof rat) create the principal rodent problems in Washington, which include great economic losses.

Biologies

The **house mouse** is a small, slender, dusky gray rodent with a slightly pointed nose, small black protruding eyes, large scantily haired ears, and a nearly hairless tail with obvious scale rings. House mice are considered among the most troublesome and economically important rodents in the United States. They are found in houses as well as other structures.

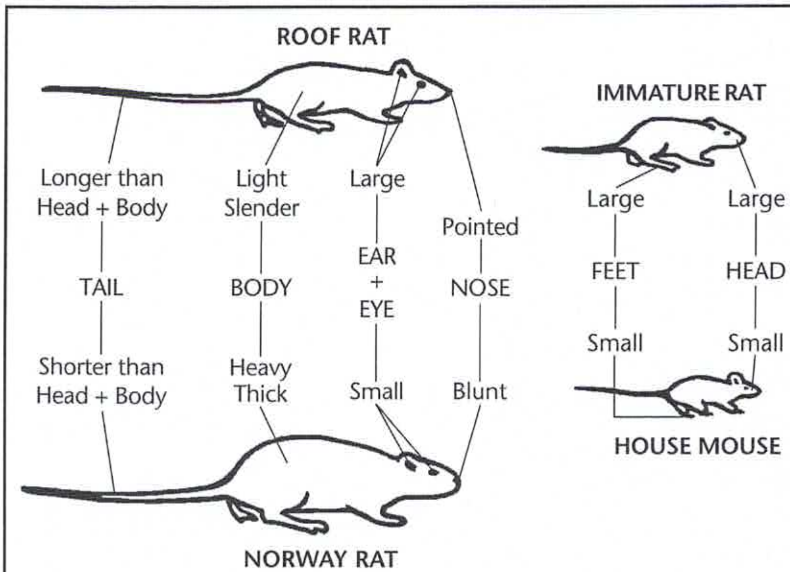
Two types of urban rats can be found in Washington: the **Norway rat** and the **roof rat**. The Norway rat (also called brown, dump, barn, sewer, gray, or wharf rat) is a burrowing rodent that is larger and more common than the roof rat. The Norway rat has a blunt muzzle, short ears, and small eyes. Its fur is coarse and usually brownish or reddish gray, with whitish gray hair on the belly. The roof rat (also called black or ship rat) is a more agile climber and has a slender body, prominent ears, and large eyes. It has several color phases, but those in Washington tend to be black or slate gray.

Sylvan (wild) rodents, including deer mice, wood rats, and some species of squirrels, may enter buildings when they are seeking harborage or food. Other mammals, such as opossums, skunks, and bats, occasionally become problems when they enter suburban or urban environments. Invasions of these nonurban animals create a health threat because of their potential to transmit parasites and disease to resident rodent populations and humans.

Normally rats and mice are nocturnal, so recognition of various signs is necessary to determine population levels. Some of these signs are burrows, gnawing activity, fecal droppings, runways, **rub marks**, and tracks.

Surveys

A rodent survey provides information on the degree of infestation and the factors favoring rodent populations. In addition it provides data for planning control programs. The data collected during postcontrol surveys are



Key to Urban Rodents

Urban Rodent Biologies

Species	Adult weight (oz)	Avg. litter size	Litters per year	Life span	Home range (ft)	Harborage	Food
Norway Rat	16	8–12	4–7	1 year	100–150	Outdoors: Burrows, garbage dumps, under foundations, lumber and trash piles	**Omnivorous**. Meat, fish, cereal, and garbage preferred
Roof Rat	8–12	6–8	4–6	1 year	100–150	Outdoors: Dense vine growth, trees, sometimes in burrows Indoors: Attics, between walls and floors, barns, in sewers	Omnivorous. Fruits, vegetables, and cereals preferred
House Mouse	0.5–0.75	5–6	5–10	1 year	10–30	Outdoors: Fields, garbage dumps Indoors: Primarily found in walls, cabinets, stored products	Omnivorous. Cereals, grains preferred

used to evaluate the effectiveness of the control program.

Rats and mice usually are not seen or observed during these surveys unless the infestation is severe. In addition to rodent signs, potential food and **harborage** situations indicate relative population densities and environmental factors favorable for rodent infestations. When the type of rodents inhabiting an area is unknown, trapping will determine the species present.

Rodent signs used in surveys include observations of rodent burrows, droppings, runways, gnawing marks, tracks, and the presence of rodent carcasses. External factors that indicate environmental potential for supporting rodent populations include the type and condition of each structure, refuse storage practices, amount of rubbish present and available rodent cover, and food supply. Examine home or building exteriors either in selected blocks or throughout the whole problem area if the area is small. Inspect building interiors if rodent infestations are severe.

Information obtained from rodent surveys shows the sanitation status in a community or area. It also shows the area's potential for supporting rodent populations. Since correcting sanitation deficiencies is basic in rodent control, environmental factors are emphasized in rodent surveys.

Management and Control

Reproduction, mortality, and movement into and out of an area determine the size of rodent populations. The physical environment, including food, shelter, water, predation, parasitism, and competition, controls population sizes. Pest control operators must consider these forces and factors when designing a lasting rodent control program.

Prevention

Preventing the initial invasion of rodents is primary. Blocking rodent access to buildings plays a major role in rodent control. Pest managers must understand rodent capabilities to prevent rodent entry. For example, rodents can run along and climb electrical wires and cables; climb trees to gain entry to a building; climb almost any rough vertical surface such as wood, brick, concrete, and weatherized sheet metal; crawl horizontally along pipes or conduit; and gnaw through a wide variety of materials, including lead, aluminum sheeting, wood, rubber, vinyl, and concrete blocks. Keep in mind that rats and mice can enter holes that are surprisingly small. Rats, for example, can gain entrance through 1/2 inch square openings. Conversely, they often enter buildings with doors left open for long periods.

To prevent rodent entry, seal all holes greater than 1/4 inch with durable materials. Steel wool packed tightly into openings is a good temporary plug to close potential entry points and protect other areas from gnawing. Fill gaps or flaws that often exist along building exteriors. Screen ventilation openings and windows. Install flashing so that doors fit tightly.

Use materials such as mortar for concrete buildings. Hardware cloth (wire mesh), galvanized sheet metal, brick, and aluminum of 22 gauge or thicker is recommended for flashing and covering openings. Choose metal grates with holes no larger than 1/4 inch for floor drains.

Sanitation

Poor sanitation is one reason for moderate to high rodent populations in urban and suburban areas. In some environments, proper sanitation cannot eliminate rodent populations, but it can often prevent rodents from flourishing in large numbers.

Sanitation involves good housekeeping, including proper storage and handling of food materials, feed, and edible garbage. Keep pet food stored in metal rodent-proof containers. Properly store and regularly dispose of garbage from homes, restaurants, warehouses, factories, and other such sources.

Sewers are inhabited by Norway rats in some cities and towns. Rats may enter at outlets and through utility access, catch basins, broken pipes, or drains. Since Norway rats are excellent swimmers, water traps do not impede their movement; in fact, they can travel upstream against a current. The problem of rats in sewers is usually greatest in places where sanitary sewers are interconnected with storm sewers, thus providing multiple entry points. The domestic sewer of an average community provides enough food to sustain a large number of rats.

Elimination of Harborage

Regular removal of debris and control of weeds from around structures will reduce the amount of shelter available to rodents. Blackberry brush, for example, is a common harborage for rats. In some instances, a strip of heavy gravel placed adjacent to building foundations or other structures will reduce rodent burrowing at these locations. In any event, keeping the periphery of buildings and structures clean of weeds, debris, and stored materials will discourage rat activity and will allow easier detection of rat signs.

Trapping

Trapping can be an effective method of controlling rodents, but it requires more skill and labor than most other methods. It is recommended where **rodenticide** use is inadvisable due to accessibility by people or pets. Trapping is the preferred method to try first in homes, garages, and other small structures where only a few rodents may be present.

Trapping has several advantages: 1) it does not rely on inherently hazardous rodenticides; 2) it permits users to view their success; and 3) it allows for disposal of rodent carcasses, thereby eliminating odor problems from decomposing carcasses when poisoning is done within buildings.

The simple, inexpensive, wooden snap trap is available in most hardware and farm supply stores. Bait traps with a small piece of hotdog, bacon, or nutmeat tied securely to the trigger. Peanut butter or marshmallows also may be used as bait. Baits that become stale lose their effectiveness. Use only fresh bait. Set traps close to walls, behind objects, in dark corners, and in places where rodent activity is seen. Place the traps so rodents following their natural course of travel (usually close to a wall) will pass directly over the trigger. Set traps so the trigger will spring easily.

Use enough traps to make the campaign short and decisive. Leaving traps unset until the bait has been taken at least once reduces the chance of rodents escaping the trap and becoming trap-shy.

Other kinds of traps also are effective in catching rodents. Wire mesh cage traps and wire funnel entrance traps can be used effectively to capture rodents alive.

Keep traps reasonably clean and in good working condition. When dirty, clean them in a hot detergent solution using a stiff brush. Human and dead rodent odors on traps are not known to reduce trapping success.

An alternative to snap traps and live traps are "glue boards," which catch and hold the rodents attempting to cross them much the same way flypaper catches flies. Place glue boards wherever rodents travel—along walls or in established pathways. Do not use glue boards where children, pets, or desirable wildlife can contact them. Glue boards lose their effectiveness in dusty areas unless enclosed in a bait box. Temperature extremes and moisture may affect the tackiness of some glues.

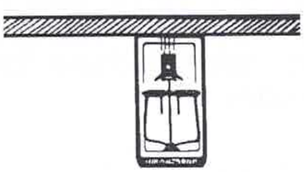
Dispose of live, trapped rodents by submerging the glue board in water to drown the animal. Sharp blows to the base of the skull will also kill the animals. If pets or children become entangled in the glue, remove the glue board by liberally applying cooking or engine oils to dissolve the adhesive.

Chemical Control

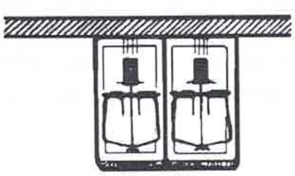
Most **rodenticides** are incorporated into food baits. It is a good practice to prebait areas with nontoxic baits to make sure the rodents will feed on it. Then add toxicants to the bait which the rodents have accepted. Make sure baits do not become rancid and otherwise unappetizing to the rodents. Keep baits out of the reach of children, pets, and other nontarget animals by using bait stations. A variety of **bait stations** are available on the market.

Multiple-dose (chronic) rodenticides are, for the most part, anticoagulants that have a

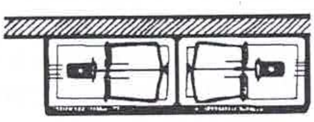
Right and Wrong Ways to Place Snap Traps



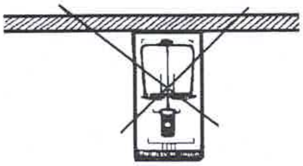
Single trap set with trigger next to wall.



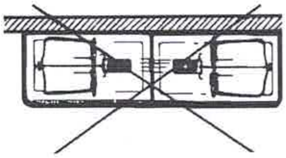
The double set increases your success.



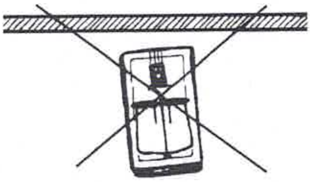
Double set placed parallel to the wall with triggers to the outside.



Wrong—trigger not next to wall.



Wrong—parallel set with triggers on the inside.



Wrong—trap too far from wall.

cumulative toxic effect on rodents. Repeated ingestion causes the animal's blood to lose its clotting ability. Death occurs from internal bleeding that begins 3 to 5 days after the first ingestion of the bait. Because they are slow acting, these compounds do not normally produce bait shyness. However, anticoagulant resistance can occur in some populations of rodents when using anticoagulant baits.

Most anticoagulant rodenticides require multiple feedings (chronic dose) to obtain a lethal dose. In Washington these include chlorophacinone, diaphacinone, and warfarin. Second generation anticoagulants on the market work after one or two feedings (acute dose); these include brodifacoum, difenacoum, and bromadiolone.

Anticoagulants have the same effect on nearly all warm-blooded animals, but sensitivity varies among species. If misused, anticoagulant rodenticides can be lethal to nontarget animals such as dogs, pigs, and cats. Additionally, residues from anticoagulants present in the bodies of dead or dying rodents can kill scavengers and predators. In general, however, the potential secondary poisoning hazard from anticoagulants is relatively low.

In the case of accidental ingestion of anticoagulants by humans or pets, vitamin K_1 or blood transfusions are effective corrective treatments. The availability of treatments, as well as the toxicant's slow action, make most anticoagulant baits among the safest rodenticides.

If rodent populations are large or pose a health hazard, the use of rodenticides that act quickly is preferred to anticoagulants fed over a long period. However, the fast-acting rodenticides (zinc phosphide, bromethalin, and cholecalciferol) generally pose more potential harm to certain nontarget species.

Tracking powders are toxicants mixed with a dust which can be used for rodent control. The toxic powder adheres to the rodent's feet and fur and is consumed during grooming. Most tracking powders incorporate anticoagulant rodenticides.

Washington has specific rules relating to the use of tracking powders (WAC 16-228-1380). The rule states that rodenticide tracking powders shall not be used in any manner that will expose people, nontarget animals, food, feed, drugs, or other consumer commodities to the powder. Tracking powders can not be used in residential structures without prior permission from WSDA.

Remember to always read pesticide labels for precautions. Keep rodenticides away from children, animals, wildlife, food, feed, and water supplies. Be aware of the proper first aid and antidotes specified in case exposure or poisoning occurs.

Application Principles

This section provides general information on equipment, application methods, and **calibration**. Information on specific pesticides can be found in the *PNW Insect Management Handbook* (MISC0047) and Extension publications printed by Washington State University.

The application of chemicals requires conscientious planning.

1. Select the equipment best suited for the application by considering weather, terrain, pest life stage, and pest population density.
2. Use the most effective pesticide registered, but balance the selection with concerns about human exposure and/or environmental impacts.
3. Read the label before purchasing, using, or disposing of the pesticide.

One problem associated with dispensing pesticides is the lack of equipment specifically designed for every pest situation. Appropriate application equipment varies depending on the method of treatment, sites where applications are to be made, pests to be controlled, and pesticide formulations. For example, some products have very short residual activity and their function is a quick knock down of the pest population, while other products act residually.

Equipment, Formulations, and Area Covered

Application Equipment	Pesticide Formulations	Treatment Area
Indoor		
Aerosol	liquid	small
Compressed air sprayer	liquid/powders	small
Dusters	dust	small
Gels	gel	small
Outdoor		
Sprayers		
compressed air	liquid/powders	small-large
hydraulic	liquid/powders	small-large
boom	liquid/powders	small-large
mist blower	liquid	small-large
Foggers (ULV)	liquid	moderate
Dusters	dust	small
Spreaders/Seeders	granular	small
Blowers	granular	small to moderate

The following two sections present basic principles for application methods and commonly used application equipment.

Application Methods

Effective pest control depends on proper understanding of the sections of the label pertaining to how the pesticide is to be applied to ensure the toxicant reaches the target area and pest. The label usually indicates the method of application to properly place the pesticide or cover the area that needs to be treated.

Space sprays or bug bombs are used for indoor pest control. They consist of an aerosol spray which produces tiny droplets that fill the air in a room or building. They may be sprayed directly onto the insects or sprayed into the air space.

Residual sprays are applied to the resting sites of adult mosquito and other insects such as plant material, culverts, the undersides of bridges, and the inner and outer walls of structures.

Mists are used outdoors to treat large areas, although some small mist machines are designed for small areas.

Fogs are dispensed as thermally-generated aerosols through combustion exhaust systems, high-pressure steam exhausts, thermal-pulse jet systems, or aerosols created by ultra-low-volume sprayers (cold foggers). Because of their small particle size, fogs generally are not suitable for larviciding. They are more widely used for adult insect control because the individual particles do not settle to the ground rapidly.

Since the distribution of these droplets depends on air currents and other climatic factors, exercise care in establishing an application schedule. Pay close attention to sensitive people and animals in the application area.

Fogs or mists are used primarily to treat large areas. The major difference between fogs and mists is the particle size: fog particles are much smaller.

Pesticide application using mists or fogs intended for extensive area coverage must be closely correlated with climatic conditions. At the time of application, a **temperature inversion** should be present and the wind should be constant in direction with no greater velocity than 5 miles per hour. Operate the application vehicle across the prevailing wind until the end of a swath is reached. At this point, interrupt the application to move the vehicle upwind to the starting point of a new swath. Again bring the vehicle crosswind. Repeat throughout the operation until completing the application.

Granulars are the most frequently used dry pesticide formulation. These are particles of bentonite, vermiculite, or other inert substances impregnated or coated with a toxicant. When applied to water as a larvicide, the toxicant is released. Granules can be applied by hand equipment, by power-driven ground equipment, and by aircraft. They either float to the surface of the water or mix with the water as emulsified particles.

Microcapsules are related to granulars. They consist of a liquid core of toxicant and an outer shell that dissolves in water.

Application Equipment

Selecting, operating, and maintaining application equipment are important. There are many types of equipment designed to deliver granules, dusts, microcapsules, residual sprays, fogs, or mist. Proper maintenance and calibration reduce concerns for drift, non-uniform coverage, and failure of a pesticide to effectively reach **target organisms**.

Choose a granular applicator that is easy to clean and fill. It should have mechanical agitation over the outlet holes. This prevents clogging and helps keep the flow rate constant. Application should stop when drive stops, even if outlets are still open. Granular applicators are speed-sensitive, so maintain uniform speed. Do not travel too fast for surface conditions. Bouncing equipment causes the application rate to vary. Clean equipment as directed by the operator's manual.

The equipment used for aerosol or fog application of insecticides is usually identified by the size of droplets it produces. These particles are expressed in units known as **microns**; 1 micron is 1/1000 of a millimeter (for comparison, the diameter of a human hair is about 50 microns). Mist blowers produce droplets ranging in size from 50 to 100 microns. Pressurized aerosol dispensers produce average droplet sizes of 25 to 50 microns. Ultra-low-volume (**ULV**) equipment produces droplets ranging from 1 to 15 microns, and foggers produce droplet sizes ranging from 0.001 to 50 microns. Space sprays are more effective when the droplets are fine (less than 50 microns) because more droplets are produced from a given quantity of insecticide in this particle size range and remain suspended in air longer.

Consider the size of your job and how to reach the target pest. There are many different types of equipment. The following is a list of the more common types.

Hand plunger dusters consist of a hand pump, metal dust chamber, and discharge tube. The duster is activated only on the positive thrust of the pump plunger. It is suitable for applying mosquito larvicide dust to small aquatic sites and for applying dust into structural openings.

Rotary dust blowers have a hand-cranked fan to create a relatively high discharge velocity air blast into which pesticide dust formulations are introduced.

Dusters are motorized units that produce a high volume, high velocity of air into which dusts are discharged for dispersion. They range from backpack units to large units that have been incorporated with mist blowers on sprayers to make a combination unit.

Horn seeders involve a canvas bag with a tapered, telescoping wand or tube located at the lower front corner of the bag. It is slung over a person's shoulder. Granules are released as the operator's arm and wand move in a horizontal motion. Application rates can be adjusted by opening the base of the wand or by changing the speed at which the applicator walks.

Cyclone-type spreaders have a cylinder with an adjustable slot in the base, through which granules fall onto a rotating disc; they are manually operated. Granules are dispersed by centrifugal force. The disc is rotated by gears activated by turning a crank handle. The rate of dispersal may be altered by controlling the size of the slotted opening or by changing the applicator's walking speed.

Granular blowers are modifications of large mist blowers so that granules can be discharged into the air exhaust ducts, or backpack dusters to permit dispersion of granules by introducing them into the outlet side of the air system.

Compressed-air sprayers have a 1- to 3-gallon tank in which air in the upper portion is put under pressure by a hand pump. The pressure created forces the spray through the nozzle. Commonly used for treating small areas with residual sprays.

Hydraulic sprayers consist of a pump that dispenses spray mixture via pressure through a nozzle or set of nozzles (boom). In some sprayers, pressures of up to 600 psi may be reached. They range in size from backpack to boat- or truck-mounted models and are commonly used for residual sprays.

For residual spraying on surfaces, the best results are obtained using a flat spray nozzle. Application is made by moving the wand of the sprayer in a direction perpendicular to the fan of the nozzle. The spray is applied until the surface is wetted to the point of runoff. Using this type of nozzle, you can make a more uniform application with less waste of material.

For aquatic habitats of mosquito larvae such as relatively narrow roadside ditches, potholes, or other small sites, the hollow cone nozzle tip on a sprayer wand is best. Depending on the size of the area involved and the availability of equipment, use either a hand-carried pressure sprayer or a mechanically powered pressure sprayer.

Mist blowers rely on air to carry the water-based pesticide solutions to the target. Special nozzles allow a large capacity of air volume for atomizing the insecticide. The average diameter of mist droplets formed is approximately 40 microns, but can range from 10 to 200 microns. Given this wide range in droplet size, an uneven distribution of the pesticide over the target area occurs even though the misting machine discharges the material at a constant rate. Generally, fogs don't penetrate cold exterior walls and depend on air currents to reach the target site. When used outdoors, wind speeds over 5 mph or rising thermal air currents can limit the effectiveness of a treatment. In general, direct fogs as near to the ground as possible and apply during evenings, nights, or early mornings. The most commonly used units are backpack models.

Thermal-fog generators break insecticides into fine droplets using hot exhaust gases. The insecticides are formulated in oil solutions vaporized in the machine. When the hot gas mixture meets with the cooler outside air, it condenses into a fog that can reach air spaces in areas highly obstructed by vegetation or buildings. Thermal foggers are electric or flame. Models that produce a flame should always be started outdoors.

Thermal fogs can cause explosions. Usually this is a result of having too high a concentration of fog in the structure and a spark or flame (such as pilot light) ignites the explosive mixture. To avoid such occurrences, shut off all pilot lights at the main gas valve before treatment. Electric switches must not be turned on or off while fog is in the air. Because of the potential for problems, allow use of equipment only by an experienced operator trained in its safe use.

Ultra-low-volume (ULV), cold-fog generators introduce low pressure-high velocity air and a pesticide concentrate into a swirl chamber, where shearing action of the air produces extremely fine droplets of pesticide. Droplet size is relatively uniform and controllable, but do not penetrate obstructed areas. Units range in size from portable aircraft mounts. These are sometimes referred to as ultra-low-dosage (ULD) applications. Distribution and effectiveness depend on the production of very small (1- to 3-micron) droplets. ULV particles float in still air for several hours.

ULV treatment is very effective against flying insects and provides good flushing action for cockroaches. It is often used after a residual treatment. When these machines are to be used in potentially hazardous atmospheres such as flour mills, electric motors must be explosion-proof; gasoline engines cannot be used.

When using ULV applications, the temperature should be above 50°F, and the insecticide and solvents should be at room temperature to achieve proper droplet size. Because droplet size is critical, equipment must be maintained and operated at specific pressures and flow rates. Disadvantages of ULV treatment include a slick residue if oversprayed, poor results in ventilated areas, and fire hazard. Generally, ULV treatments have a shorter treatment time and lower fire hazard than thermal foggers.

Aircraft apply either liquid spray or granular materials. For sprays, a boom with appropriate nozzles is mounted on the aircraft. For granular applications, a spreader is mounted. Both fixed-wing and rotary-wing aircraft are used. Both can make applications to large areas, including those otherwise inaccessible.

Aerosol dispensers (bug bombs) consist of a disposable container charged with an inert gas and an appropriate insecticidal solution. They are designed for indoor space spraying and crack/crevice treatment by discharging a fine mist. They are convenient to use because they require no special motors, water, or mixing, but they are relatively more expensive per unit of insecticide. Keep pressurized aerosols from freezing. High temperatures can cause explosions, so do not keep in warm areas like a vehicle or storage area. Low temperatures result in a drop in pressure and improper droplet size. Some aerosol cans are available with a plastic extension tube, which allows better placement of materials into cracks and crevices.

Sprayer Equipment

Tanks should have large openings for easy filling and cleaning, allow straining during filling, and provide for mechanical or hydraulic agitation. Use tanks constructed of a corrosion-resistant material, such as stainless steel or fiberglass. If made of mild steel, tanks should have a protective lining or coating.

Tanks should have large drains, and other outlets should be sized to the pump capacity. A gauge is needed to show the liquid level in the tank. Protect external gauges to prevent breakage. Make sure your tank has a cutoff valve for storing liquid pesticide temporarily while other parts are being serviced.

Pumps must have sufficient capacity to supply the needed volume to the nozzles and hydraulic agitator (if applicable), and to maintain the desired pressure. The pump parts should be resistant to corrosion and abrasion if abrasive materials such as wettable powders are to be used. Select gaskets, plunger caps, and impellers resistant to the swelling and chemical breakdown caused by many liquid pesticides. Consult your dealer for available options.

Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. Pumps will be damaged if run dry or with a restricted inlet or outlet since they depend on dissipation of liquid for lubrication and heat.

Strainers (filters) remove dirt, rust flakes, and other foreign materials from the tank mixture. Proper filtering protects the working parts of the sprayer from undue wear and avoids time loss and uneven application caused by clogged nozzle tips.

Filtering should be progressive, with the largest mesh screens in the filler opening and suction line between the tank and the pump. Key these to the size of the nozzle opening. The total screen area should be large enough to prevent pump starvation. Do not use a strainer in the suction line of a centrifugal pump.

Make sure strainers are on the filler opening, on the suction or supply line to the pump, between the pressure relief valve and the boom, and on the nozzle body. Clean strainers after each use. Replace damaged or deteriorated strainers.

Strainers are your best defense against nozzle plugging and pump wear. Nozzle screens should be as large as the nozzle size permits; however, the screen opening should be smaller than the nozzle opening. Nozzle catalogs specify the proper screen size for each nozzle.

Hoses should be synthetic, rubber, or plastic with a burst strength greater than peak operating pressures, resist oil and solvents present in pesticides, and are weather resistant. Keep hoses from kinking or being rubbed. Rinse them often, inside and out, to prolong life. Store them out of the sun. Replace hoses at the first sign of surface deterioration.

Pressure gauges monitor your spray system. Gauges must be accurate and have the range needed for your work. For example, a 0 to 100 psi gauge with 2-lb gradations is adequate for most sprayers. Check frequently for accuracy. If the gauge does not return to zero when not operating, replace it.

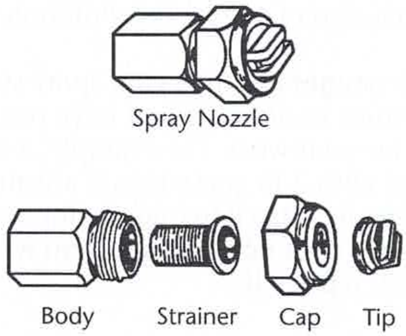
Pressure regulators control the pressure and, indirectly, the quantity of spray material delivered by the nozzles. They protect pump seals, hoses, and other sprayer parts from damage due to excessive pressure.

Agitators mix the components of a spray mixture uniformly and, for some formulations, keep the material in suspension. If agitation is inadequate, the actual application rate of the pesticide may vary as the tank empties. The most common types of agitators are hydraulic and mechanical. Hydraulic agitation is accomplished by recirculating the spray mix through nozzle jets located in the spray tank. Large revolving paddles inside the spray tank provide mechanical agitation.

Control valves should be quick-acting and located between the pressure regulator and the nozzles to provide positive on-off action. Make sure cutoff valves to stop all flow or flow in any section of the spraying system are within easy reach of the sprayer operator.

Nozzles are made up of four major parts: nozzle body, cap, strainer (screen), and tip or orifice plate. They also may include a separate spinner plate. Successful spraying depend on correct selection, assembly, and maintenance as per manufacturer requirements.

Nozzle tips break liquid into droplets, distribute the spray in a predetermined pattern, and are the principal element controlling the rate of application. Nozzle performance depends on nozzle design or type, operating pressure, size of the opening, discharge angle, and distance of the nozzle from the target.



Parts of a Nozzle

Nozzles are available in several materials. Tungsten carbide and ceramic nozzles are the most resistant to abrasion and corrosion, but also the most expensive. Stainless steel nozzles have good corrosion and abrasion resistance if hardened, and are moderately priced. Plastic nozzles will not corrode, resist abrasion better than brass, and are moderately expensive, but may swell when exposed to organic solvents. Brass nozzles resist corrosion (except from fertilizers) but not abrasion, and are moderately expensive. Aluminum nozzles are inexpensive and resistant to some corrosive materials.

Operating and Maintaining Sprayers

Properly operating and maintaining spray equipment is critical for safe and effective pesticide applications, minimizing repair costs, and prolonging sprayer life.

Always read and follow the operator's manual for exactly how to use and care for all your spray equipment. After each use, rinse out the entire system (apply rinsate to application site). Check for leaks in lines, valves, seals, and tank. Remove and clean nozzles, nozzle screens, and strainers.

Check nozzles for unusual patterns. If emergency repairs or adjustments are necessary in the field, always use adequate protective clothing, particularly rubber gloves. Use an old toothbrush to unclog nozzles. Never use metal wire to unclog a nozzle because it may distort the nozzle opening and change the spray pattern and output.

To prepare spray equipment for storage, rinse and clean the system. Add 1 to 5 gallons of light-weight emulsifiable oil (depending on the size of the tank) to an equal volume of clean water. Flush the entire system with the oil and water mixture. As the mixture is pumped from the sprayer, the oil will leave a protective coating on the inside of the tank, pump, and plumbing. Remove nozzles and nozzle screens, and store in a dry place to prevent corrosion.

Equipment Calibration

The effectiveness of any pesticide depends on the proper application and placement of the chemical. Calibration ensures that applic-tion equipment uniformly applies the correct amount of material over a given area. Even if you have the correct chemical mixure, it is still possible to apply the wrong amount if your equipment is not calibrated properly. Too little pesticide results in poor pest control. Too much pesticide may result in environ-mental and human health problems and is a waste of money. The recommended pesticide delivery rate changes with equipment wear, gauge error, and nozzle wear.

Application equipment suppliers often provide charts and tables to help you determine equipment set-up and approx-imate desired delivery rates; however, such sources of information do not account for equipment wear, inaccurate gauges, or inaccurate speedometers. You must therefore periodically calibrate equipment to obtain reliable delivery rates.

Sprayer Calibration

Calibration is simply determining the equipment's delivery rate, or amount of material delivered (applied) from the application equipment over a known area.

Proper sprayer function is essential to accurate sprayer calibration; therefore, the following procedures are recommended before carrying out calibration.

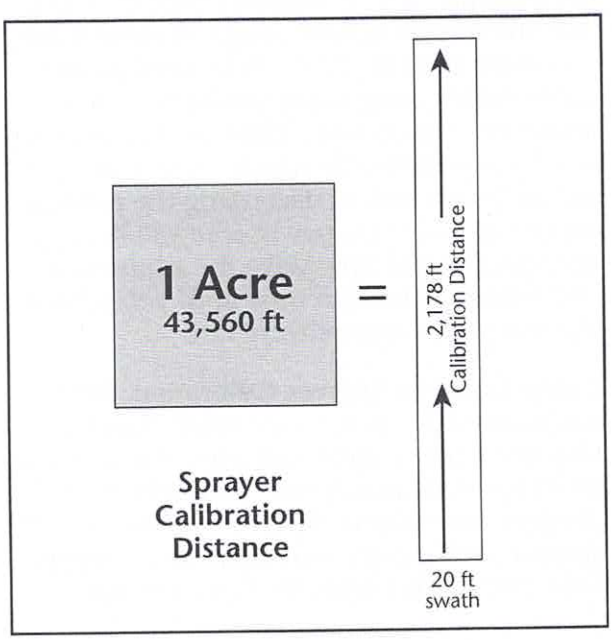
- Be sure sprayer nozzle tips are appropriate for the kind of spray application to be made.
- Thoroughly clean all nozzles, nozzle tips, and screens with a soft brush to ensure proper operation. Add water to the spray tank and visually check the nozzle output during sprayer operation. Discard and replace any nozzle tips producing distorted spray patterns.
- If possible, check the spray volume delivery of all nozzles and replace any nozzle tips whose delivery deviates more than 10% from delivery rates indicated in equipment catalogs.
- If the sprayer has a pressure gauge, check it out. If the gauge is rusty or of questionable accuracy, replace it. This is especially important if delivery rates are taken from spray charts or tables.

Sprayer calibration is designed to determine the amount of spray the equipment is delivering per unit area. Most labels direct the user to apply a specified amount of the pesticide per acre, but some label instructions include specifications for an amount of pesticide to be applied per 1,000 square feet or some other area measure.

Boom Sprayer Calibration. The following calibration method is one of the most accurate for boom sprayers.

- Select a reasonable operating travel speed for the terrain and relative durability of the spray equipment. Record the tachometer or speedometer reading and the gear setting used to maintain the selected speed.
- Select and record the spray pressure at which the system will be operated. Adjust the pressure to the desired psi while the pump is operating at normal speed and water is flowing through the nozzles. (Minimize off-target drift by operating at the lower end of a nozzle's pressure range.)
- Measure the total boom swath width to the nearest whole foot by spraying on a dry, flat surface such as a parking lot or road.
- Determine the spray distance necessary to cover a full acre (43,560 square feet). Example: if the swath width is 20 feet, then 43,560 square feet ÷ 20 feet = 2,178 feet. The sprayer must travel 2,178 feet to cover an acre.
- Measure and mark the distance necessary to cover an acre.
- Using only water, fill the tank to a known level, mark that level, and mark the exact place on the ground where the sprayer is situated.
- With a running start, spray the measured distance.
- Return to the exact site where the tank was originally filled and measure the amount of water required to refill the tank to the original level. This normally involves the use of a pail of known capacity.
- The number of gallons necessary to refill the tank is the sprayer delivery rate in gallons per acre (GPA).

Sprayer calibration results are valid only for the speed, nozzles, pressure, and spray width (swath) used during the calibration process. Significant changes in any one of these factors will require another calibration check. Calibrate your sprayer more than once per season.



Only if you know the sprayer delivery rate and can determine the sprayer tank capacity can you determine the amount of product to add to the spray tank.

Example: A label directs applying 3 pints of a pesticide formulation per acre. If your sprayer calibration indicates the sprayer delivery rate is 20 GPA and the spray tank capacity is 100 gallons, how much product should you apply with each tank load of spray?

First, determine the number of acres each tank load will cover. If the sprayer delivers 20 GPA (at the speed and pressure at which it was calibrated) and the spray tank holds 100 gallons, then the number of acres a tank load will cover = 100 ÷ 20 or 5 acres. If the label directs you to apply 3 pints per acre and a tank load will cover 5 acres, then the amount of pesticide that must be mixed per tank load is 3 pints x 5 acres = 15 pints.

If the area to be sprayed is smaller than the area covered by a full tank load, you must mix a partial tank load. For example, if the sprayer delivers 20 GPA and the area to be covered is 3 acres, how many gallons of spray mix should you prepare? (3 acres x 20 GPA = 60 gallons of spray mix). If you are applying 3 pints of formulation per acre, how much formulation do you need for this application? (3 acres x 3 pints per acre = 9 pints of product). Mix 9 pints of product in 60 gallons of water to cover the 3 acres.

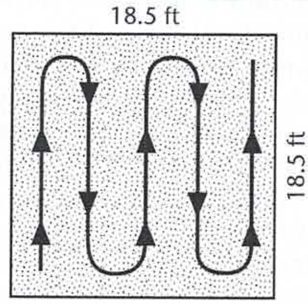
Sprayer delivery rates are easily adjusted. For example, if a calibration check indicates that the sprayer is delivering less spray than necessary, increase the GPA by slowing the travel speed, using larger nozzle orifices, or increasing the pressure. Decrease the delivery rate by increasing the speed, using a smaller nozzle orifice size, or decreasing the pressure. Make any major change in sprayer GPA by changing nozzle tips. Make the adjustments and repeat calibration runs until you achieve the desired sprayer delivery rate.

Compressed Air Sprayer Calibration. Most compressed air sprayers are small, hand-operated and carried units; consequently, application factors such as speed, spray width, and pressure are variable. Calibrating this kind of sprayer provides a rough estimate of sprayer GPA, but this is preferable to no estimate.

The following is one method used to calibrate hand pressurized sprayers:

- Measure and mark a square area 18.5 feet x 18.5 feet, preferably on a surface which will readily demonstrate the spray pattern width (e.g., a paved parking lot).
- Empty liquid spray tank residues, and using a container graduated in ounces, add 2 quarts (64 ounces) of water to the spray tank.
- Pressurize the sprayer and spray the area defined by the marked square. Maintain uniform operator walking speed, nozzle height, and tank pressurization to the extent possible.
- Depressurize the spray tank by opening the filler cap; drain the spray wand back into the tank by holding the spray wand above the tank and opening the spray valve on the wand.
- Using the container graduated in ounces, determine the number of ounces remaining in the sprayer.
- Determine the number of ounces sprayed by subtracting the number of ounces left in the sprayer from the 64 ounces originally added to the spray tank.
- The number of ounces sprayed on the defined area is equal to the gallon per acre delivery of that sprayer. For example, if the number of ounces used to cover the defined area is 36, then the sprayer is delivering about 36 gallons per acre.

Remember, this is a rough estimate and applies only to the operator who calibrated the sprayer.



Calibration Area for Compressed Air Sprayers

Granular Applicator Calibration

Calibrate granular applicators with the same material that is to be applied. The calibration method must provide a means for collecting and weighing the granules.

For broadcast applicators, select a check plot with a known area. Determine the swath width of the application equipment. Disconnect the spreading mechanism (if one is used) and attach a catch pan, plastic or other bag, or any appropriate container to catch the granules. Operate the applicator at the desired settings and travel speed with the pesticide to be applied only over the measured plot, and catch all the material that flows through the unit. Weigh the collected granules. This gives you the amount of material applied per unit area (pounds per acre or pounds per thousand square feet).

> **Example:** When operated at the height above the ground and at the rotor speed you have chosen, your spreader produces a 25-foot swath. If you calibrate the spreader over a check plot of 0.25 acre, calculate how far you would have to travel in a straight line to cover 0.25 acre with a 25-foot swath (0.25 acres x 43,560 square feet/acre = 10,890 square feet, so 1/4 of an acre is 10,890 square feet). If your swath is 25 feet, to cover 10,890 square feet you must travel 436 feet (10,890 square feet ÷ 25 feet = 435.6 feet). Measure and mark this distance, and measure the amount of granules caught in the catch pan over your 436-foot path. If you captured 15 pounds of granules over this area (15 pounds/0.25 acres), then you would apply 4 x 15 pounds or 60 pounds over a whole acre. Adjust the setting and rerun until you achieve the desired delivery rate.

Treatment Types and Calculations

Pesticides used for control of public health pests will be labeled for application as space treatments, spot treatments, crack and crevice treatments, perimeter treatments, or area treatments.

Space treatments usually require you to seal a building and either release a self-propelled formulation or spray a mist into the air within a structure. Ready-to-use formulations are most common.

Spot treatments, crack and crevice treatments, and perimeter treatments are applications to specific areas where pest problems occur (where pests hide or rest, baseboards, closets, under sink), as compared with general treatments over an entire area where pests may reside. Directions for spot or crack and crevice treatments are common for pesticides labeled for indoor applications. Generally the directions state to spray the solution to the point of wet or runoff.

Pesticide solutions are made up on a volume basis (amount of pesticide formulation per unit of water such as 4 ounces of pesticide per 3 gallons of water). This solution is then applied where necessary. Be careful to assess how much area you will treat so you can make enough solution to do the job, with none left over.

> **Example:** The label directs you to apply 3 ounces of a pesticide per gallon of water to treat for cockroaches as a coarse low pressure spot or crack and crevice treatment. You have a 3-gallon sprayer which you estimate will do 4 of the 6 apartments that need treatment. How much water should you put in the sprayer for the last 2 apartments, and how much pesticide do you need to add to the tank?
>
> If 3 gallons does 4 apartments and all the apartments are quite similar in total area needing treatment, you can assume the next 2 apartments will take 1.5 gallons of water (1/2 x 3 = 1.5 gallons).
>
> The label directs you to mix 3 ounces of pesticide for each gallon of water. You have 1.5 gallons of water in the tank, so you will need 4.5 ounces of pesticide (1.5 x 3 ounces = 4.5 ounces).

Many applications are made to general areas, and labels base the application on the amount of area to be treated. Surface area measurements form the base for surface applications, whether for mosquito larvae in a pond or for ticks in a carpet.

> **Example:** The label rate of a mosquito larvicide is 8 gallons of formulation per surface acre. The larval

infestation in your shallow, marsh pond covers an area 500 feet by 750 feet. How much product do you need to make a complete application?

First, determine how many acres of surface you must treat (500 feet x 750 feet = 375,000 square feet). This is how many acres? (375,000 square feet ÷ 43,560 square feet in an acre = 8.6 surface acres)

If you must apply 8 gallons of product per acre and you have 8.6 surface acres, then 8.6 acres x 8 gals. product/acre = 68.8 or 69 gallons of the product.

Example: The label directs you to apply a solution (3 ounces of pesticide per gallon of water) to an area to control ticks or fleas in a building, including rugs and furniture. The label rate is 1 gallon of solution per 800 square feet.

First calculate the footage in the house where you will make the application to control these pests. You have determined that as 2,200 square feet, how much solution do you need? How much water will you need to do the job? How much pesticide do you need to do the job?

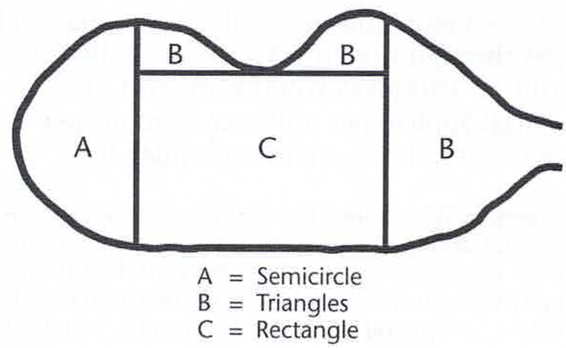
Solution: 2,200 square feet ÷ 800 square feet (1 gallon covers) = 2.75, so you need 2.75 gallons of solution.

Water: 2.75 gallons of solution would require just shy of 2.75 gallons of water because you will add pesticide.

Pesticide: 3 ounces per gallon of water is the label rate. Your job requires 2.75 gallons of water. You need (3 ounces x 2.75 gallons of water = 8.25 ounces) 8.25 ounces of pesticide for the job.

If you only had a 1-gallon sprayer, how many times would you have to mix the solution? Refill 2 times at 1 gallon each (3 ounces pesticide) and 1 time with 0.75 gallons of water (2.25 ounces pesticide: 0.75 x 3 ounces = 2.25).

The surface areas of odd-shaped treatment sites sometimes can be cumbersome, especially if they involve circular borders. Break the area up into smaller units from which you can more easily make area measurements.



Area Measurements

Equivalents and Equations

Liquid Measurements

1 gallon (gal)	=	4 quarts or 8 pints or 16 cups or 128 ounces (fl oz)
1 quart (qt)	=	2 pints or 4 cups or 32 ounces
1 pint (pt)	=	2 cups or 16 ounces
1 cup	=	8 ounces or 16 tablespoons
1/2 cup	=	4 ounces or 8 tablespoons
1/4 cup	=	2 ounces or 4 tablespoons
1 tablespoon	=	1/2 ounce

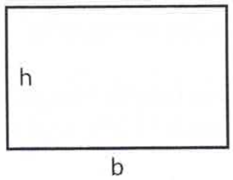
Solid Measurements

1 pound (lb)	=	16 ounces
1/2 pound	=	8 ounces

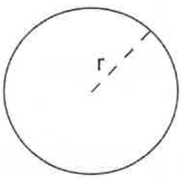
Area Measurements

1 acre = 43,560 square feet

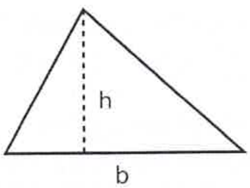
area of: square or rectangle = base x height; or length x width



circle = πr^2 or 3.14 x (radius of a circle)^2



triangle = 1/2 x base x height



Glossary

Abatement. Reduction in pest populations to an acceptable level.

Adulticide. An insecticide which is toxic to the adult stage of insects.

Aerosol. A suspension of very fine solid or liquid particles in a gas. Particle diameters vary between about 0.1 and 50 microns.

Arthropod. A large group of organisms characterized by a hard external covering called an exoskeleton and appendages composed of rigid segments with flexible joints between them. Examples are insects, spiders, scorpions, and ticks.

Arthropod-borne Encephalitis. A disease which may be caused by one of a number of viruses and is transmitted to humans by mosquitoes or ticks. Mosquito-borne encephalitis is present in Washington. Depending on the strain of virus, the fatality rate varies between 5% and 60%.

Bait Station. A device that holds bait and closes securely to prevent children and pets from access.

Biological Vector. See "vector."

Blue Tongue. A viral disease of sheep, goats, and cattle transmitted by certain biting midges.

Brood. A group of individuals that hatch at one time from eggs laid by the same parents.

Calibration. Measuring and adjusting pesticide application equipment's delivery rate per area given the settings for application speed, equipment pressure, and delivery flow rate (depending on the gate opening or nozzle type and size).

Cocoon. A protective, often silky material that surrounds the pupae of some insects undergoing complex metamorphosis.

Colorado Tick. A virus disease of small mammals which may be transmitted to humans by the bite of an infected tick.

Complex Metamorphosis. The development of some higher insects through four distinct stages, all appearing very different in form: egg, larva, pupa, and adult.

DEET. A common insect and tick repellent.

Dermatitis. Inflammation or irritation of the skin.

Detritus. Dead organic tissues and organisms and the living organisms involved in their decomposition.

Diapause. A period of spontaneous dormancy or suspended animation between periods of activity in arthropods.

Disease. A condition in which any part of a living organism is abnormal.

Dorsal. Toward or referring to the top or back of an animal. The opposite of ventral.

Ecology. The study of the relationships of plants and animals to each other and to their environment.

Ectoparasite. A parasite which lives on the outside of its host's body. Fleas, lice, and ticks are examples.

Encephalitis. See "arthropod-borne encephalitis."

Enteric Disease. A disease of the intestines or gastro-intestinal tract in general.

Exoskeleton. A hard shell of arthropods to which their muscles are attached. Serves the same function as the bony skeleton of humans.

Habitat. The place where a plant or animal lives.

Hantavirus. A very serious respiratory illness from dried urine, saliva, and droppings of deer mice.

Harborage. The shelter where animals live or hide.

Insecticide. A pesticide with an insect or other arthropod as the target organism.

Instar. The stage or period between molts in insect larvae. The first instar is the stage between the egg and the first molt; the second instar is between the first and second molts, etc.

Invertebrate. Animal without a backbone.

Larva. An immature insect that hatches from the egg in a form fundamentally different from the adult, and that passes through a pupal stage before becoming an adult. Larva also may refer to the 6-legged stage of ticks.

Larvicide. An insecticide toxic to insect larvae.

Leptospirosis. A disease caused by a spiral-shaped bacterium and usually transmitted to humans by way of food or water contaminated with urine from an infected animal, or by direct contact with an infected animal.

Life Cycle. The period between 1) the fertilization of an egg and the normal death of the individual from the egg; or 2) egg laying and sexual maturity of the individuals that hatch from the eggs.

Lyme Disease. A disease caused by spiral-shaped bacteria and transmitted by ticks. Sixteen cases of this disease were reported to the Washington State Department of Health in 2009.

Metamorphosis. The striking changes in shape and structure that occur as an insect progresses from one stage in its life cycle to the next.

Micron. A measure of length equal to one thousandth of a millimeter (0.001 mm), or about one twenty-five-thousandth of an inch.

Myiasis. Invasion of the tissues of a live animal by fly larvae.

Nocturnal. Active at night.

Nymph. An immature insect that hatches from an egg in a form similar in appearance to the adult, but with wings and sex organs incompletely developed. Nymphs do not pass through a pupal stage before becoming adults.

Omnivorous. Eats a wide variety of foods, including both plant and animal material.

Ootheca. The egg case of some insects.

Organism. A living creature.

Oviposition. Egg laying.

Parasite. An organism that derives nourishment from another at the expense of the other, but without immediately killing it.

Pathogen. A disease-causing organism.

Pesticide. A chemical intended to kill, control, repel, or mitigate a pest organism.

Phytotoxicity. The ability of a chemical to cause injury to plants.

Plague. A bacterial disease of rodents that may be transmitted to humans by the bite of an infected flea or direct contact with the tissues of an infected rodent. The most common form is bubonic plague, but some human cases progress to the highly contagious pneumonic form. Pneumonic plague was the "black death" that caused the pandemics in Europe and Asia during the Middle Ages.

Predator. An animal that kills and eats other animals.

Proboscis. The extensible mouth parts of certain flies.

Public Health Vector. See "vector."

Pupa. An immature insect stage between the larva and the adult.

Reservoir. A host species that tolerates the development or multiplication of a parasite without serious harm. Such a reservoir may serve as a source of infection for other hosts in which the parasite causes disease.

Rickettsia. A microscopic organism intermediate in size between viruses and bacteria.

Rocky Mountain Spotted Fever. A disease caused by a rickettsia that is transmitted to humans by the bite of an infected hard tick or contamination of skin with tissues from an infected tick (e.g., by crushing the tick).

Rodenticide. A pesticide that targets rodents.

Rub Mark. Dark, oily mark left on a surface by rats repeatedly passing by.

Salmonella. A bacterium transmitted by some insects that causes enteric infections.

Scabies. A disease caused by the presence of itch mites.

Simple Metamorphosis. The development of some insects with little change in appearance of the young and adult: egg, nymph, and adult.

Species. A group or population of individuals that interbreed or are capable of naturally interbreeding to produce viable offspring.

Sylvan. Of the woods or forest. Sylvan plague can be found in wild rodents, rabbits, and hares. The word "wild" can be substituted for sylvan without significantly changing the meaning.

Target Organism. The plant or animal against which a pesticide is directed.

Temperature Inversion. Where the air temperature increases from the ground up to some point a few feet to hundreds of feet above the ground, beyond which the temperature progressively decreases with increasing height. The more common situation is where the temperature steadily decreases with increasing height above the ground. Temperature inversions tend to hold pesticide fogs, smoke, and other air pollutants close to the ground.

Tick-borne Relapsing Fever. A disease caused by spiral-shaped bacteria and transmitted to humans by the bite of soft ticks.

Tularemia. A bacterial disease of rodents and rabbits which may be transmitted to humans by the bite of certain flies or ticks, direct contact with tissues of infected animals, or drinking water contaminated with the bodies of infected animals.

ULV. Ultra-low-volume application.

Vector. An animal, usually an arthropod, capable of transmitting a disease-causing agent or parasite from one host to another. In the case of a biological vector, the disease agent or parasite completes a part of its life cycle or increases in number while in the vector. A mechanical vector simply carries the disease agent from one host to another. "Public health vectors" are defined as flies or mosquitoes in sufficient numbers to be detrimental to human health and well-being.

Ventral. Toward or referring to the belly or underside of an animal. The opposite of dorsal.

Vertebrate. An animal that has a backbone: fishes, amphibians, reptiles, birds, and mammals.

West Nile Virus. A disease caused by a virus and transmitted by mosquitoes. The main host is birds; humans and horses appear to be incidental hosts. The most serious manifestation of West Nile Virus is fatal inflammation of the brain (encephalitis).

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