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Wyoming Aquatic Pest Control: Category 905

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DEPARTMENT OF AGRICULTURE PESTICIDE PROGRAMS

This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education.

Colorado

- 303-869-9063
- https://www.colorado.gov/pacific/agplants/pesticides

Montana

- 406-444-5400
- http://agr.mt.gov/agr/programs/pesticides/

North Dakota

- 701-328-2231
- https://www.nd.gov/ndda/program/pesticide-applicator-and-dealer-certification

South Dakota

- 605-773-4432
- https://sdda.sd.gov/ag-services/pesticide-program/

Utah

- 801-538-7100
- http://ag.utah.gov/pesticides.html

Wyoming

- 307-777-7324
- http://wyagric.state.wy.us/divisions/ts/sections-a-programs/pesticide

PESTICIDE SAFETY EDUCATION PROGRAMS

These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos.

COLORADO

- Colorado Environmental Pesticide Education Program (CEPEP)
- cepep.agsci.colostate.edu
- 970-491-3947
- 1177 Campus Delivery
  Colorado State University
  Ft. Collins, CO 80523-1177

MONTANA

- Montana State University Pesticide Education Program
- www.pesticides.montana.edu
- 406-994-5067
- Montana State University
  103 Animal Bioscience
  Bozeman, MT 59717-2900

NORTH DAKOTA

- North Dakota Pesticide Training and Certification Program
- www.ag.ndsu.edu/pesticide
- 701-231-7180
- North Dakota State University Extension Service
  NDSU Dept 7060
  P.O. Box 6050
  Fargo, ND 58108-6050

SOUTH DAKOTA

- South Dakota Department of Agriculture Licensing and Education
- http://sdda.sd.gov/ag-services/pesticide-program/certification-licensing-registration/licensing-and-education/default.aspx

UTAH

- Utah State University
- Mike Whitesides, 435-797-7613

WYOMING

- University of Wyoming Pesticide Safety Education Program
- uwyoextension.org/psep/
- 307-837-2956
- University of Wyoming
  2753 State Highway 157
  Lingle, WY 82223-8543

NATIONAL PESTICIDE INFORMATION CENTER (NPIC)

- Oregon State University
- 800-858-7358
- http://npic.orst.edu
- Information about pesticides and pesticide-related topics.

Equivalent Category Numbers by State

State	Aquatic	Public Health	Outdoor Vertebrate
Colorado	108	110	302
Montana	36	38	N/A
North Dakota	N/A	Public Health Pest Control	Vertebrate Pest Control
South Dakota	6	91	2 and 13
Utah	5(a)	81	2
Wyoming	905	908 and 911-O (Mosquito)	N/A

INTRODUCTION

Aquatic pest control is defined by the Environmental Protection Agency (EPA) as the application of pesticides to standing or running water, except for pesticide applications which are included in the Public Health category.

USING THIS GUIDE

This manual is intended to provide the information necessary to achieve specialized certification for aquatic applicators in Colorado, Montana, South Dakota, Utah, and Wyoming. This guide should not be regarded as an extensive overview of pesticide application to aquatic species in these states. It is not a comprehensive study of all aquatic pests and pesticide safety. It should be read in addition to the Core Manual solely as a means of preparing for the Aquatic Pest Control exam.

This guide covers key pests in aquatic ecosystems. It covers some fish, invertebrate, and vertebrate pests, but is mainly focused on aquatic weeds. Please keep in mind that most states have a separate category for public health, which generally includes mosquito control.

In addition, many states have specific outdoor vertebrate pest management certification categories. Check with your local extension educator before beginning a vertebrate pest control program to ensure that you have the proper certifications.

For the equivalent category numbers for the states in our region see page 2.

PREPARING FOR THE EXAM

The aquatic pest control exam consists of both true-false and multiple-choice questions. To prepare for the aquatic pest exam, read this study guide and the pertinent laws and regulations pertaining to pesticide application in your state. Each state has its own exam; questions will come from this guide and your state's pesticide laws. You are responsible for acquiring and understanding your state's laws and regulations.

LEARNING TOOLS

The **Learning Objectives** at the beginning of each chapter highlight the key information you should understand and be familiar with before taking the aquatic pest control exam.

A list of **Additional Resources** is included at the end of each chapter. The section is included to provide you with additional information above and beyond what is presented in this study guide.

The **Glossary**, see page 150, will familiarize you with terminology used in the text. Terms that appear in the glossary are in boldface type when they are first used in the guide.

In addition, a **Technical Appendix**, see page 144, and a **List of Abbreviations**, see page "List of Abbreviations" on page 148 are included.

INTEGRATED PEST MANAGEMENT

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Explain why pest identification is the first step in developing an effective pest control strategy

B. Define Integrated Pest Management (IPM) and describe pest management methods, giving examples, that may be included in an aquatic IPM program

C. Understand action thresholds

D. Understand why scouting is important and how to scout effectively

E. Describe non-chemical pest control methods, including prevention, mechanical, cultural, and biological methods

F. Understand when to use chemical controls

INTRODUCTION

Residents of the Western states are privileged to live in an area of clean, fresh, and abundant **watersheds** and reservoirs. Our recreational water use includes boating, swimming, kayaking, canoeing, and fishing, but these activities can be impeded by aquatic pests. Our attractive waters can become undesirable when invaded by aquatic **pests**.

Aquatic pests may include algae, flowering plants, invertebrates, and vertebrates. These organisms are considered pests when they compromise the economic, environmental, or recreational uses of a body of water. This may take the form of aesthetic degradation like unsightly masses of algae, recreational interference like dense growths of aquatic plants that impede boats and swimmers, and ecological damage such as an overpopulation of carp which may ruin habitat for more desirable species. In addition, aquatic weeds may compromise public health by providing good habitat for disease-**vectoring** organisms like mosquitoes.

Aquatic pest management techniques are often very different from terrestrial methods. Management goals and plans must be tailored to each water body, because each is unique. Because these systems are interconnected, an action taken at one point in a watershed may have serious consequences downstream. Understanding watersheds as far-reaching systems is fundamental to safely and effectively managing aquatic pests.

PESTS AND PEST CONTROL

Correct pest identification and knowledge of their development and behavior are key to effective pest control. Diagnosing pest problems is a science, and experience is important. When you find a pest or pest problem you cannot identify, ask an expert to help you.

When you have identified a pest, you must decide how to manage it. Remember, even though a pest is present, it may not be very harmful. In determining if pest control is necessary, one must consider whether the cost of control would be more than the economic loss from the pest's damage.

If control is necessary, determine the level of pest control you need: **prevention**, **suppression**, or **eradication**. Then, choose the methods that will do a cost-effective job of managing the pest while causing the least possible harm to people and the environment.

Pesticides are a valuable tool, but they should be used only when and where they are needed. Consider **chemical control** when pest numbers or the damage the pests are causing is unacceptable, when other pest management methods will not provide effective control, or when your knowledge of the situation indicates that you need to use a pesticide preventively.

Remember, never try to control any pest until you know what it is. If you use a pesticide, follow the **label** directions carefully.

WHAT IS IPM?

The management of aquatic pests rarely relies on a single control practice; usually, a variety of tactics are integrated to maintain pests at acceptable levels. **Integrated Pest Management** (**IPM**) is an approach to the management of pests in which all available control methods are evaluated and integrated into a unified program. Control methods used in IPM include:

- physical/mechanical
- cultural
- biological
- chemical

Applying multiple control methods minimizes the chance that pests will adapt to any one method.

IPM programs use current, comprehensive information on pest **life cycles** and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible **hazard** to people, property, and the environment. The goal of IPM is not to eliminate all pests; some pests are tolerable and essential so that their natural enemies remain in the environment. Instead, the aim is to reduce pest populations far enough that they are not economically damaging.

Pest control measures, whether chemical or cultural, rarely affect the targeted pest species alone, but in many cases also influence other components of the ecosystem, especially in aquatic systems. Sometimes control measures can adversely affect the environment by contaminating water, causing soil erosion, or harming wildlife or wildlife habitat.

The challenge of successful land and water management is to use those control practices which provide the most acceptable balance between the management objective and any undesirable environmental effects.

HOW DOES IPM WORK?

IPM is not a single pest control method but rather a series of pest management evaluations, decisions, and controls. In practicing IPM, a four-tiered approach is used:

1. Identify the problem and set **action thresholds.**
2. **Scouting.**
3. Prevention.
4. Control.

Economic justification for control

Before taking any pest control action, IPM first sets an action threshold or **economic threshold**, a point at which pest populations indicate that pest control action must be taken to prevent significant economic, recreation, or **native** species habitat loss. The term action threshold implies that when a pest population reaches this threshold, unless it is controlled in some manner, significant damage from the pest is expected. Once an area has reached an action threshold, however, the area should be evaluated. The growth stage or size of individual pests, weather, and other factors will influence the decision to apply a pesticide or utilize a different control tactic.

Scouting

The key to a successful IPM program is regular scouting and monitoring of aquatic site conditions and pest populations.

Pests can be scouted in several ways. Most methods involve counting the numbers of pests present or estimating the amount of pest damage. Estimated damage is usually expressed as a percentage of the total area or water volume.

When evaluating aquatic sites, it is vital to take note of many factors, including:

- the location of the body of water;
- how the body of water is being used (recreation, irrigation, municipal);
- the history of water use and previous management practices;
- the goals, attitudes, and expectations of water users;
- where water flows in and out of the site;
- the number, age, size, ecological role, and abundance of any fish species that are present;
- the diversity of birds, **animals**, and other organisms that depend on this body of water;
- the native and non-native vegetation that is present;
- the physical characteristics of the water body, such as depth, surface area, sedimentation, and shape;
- the quality and appearance of the water's edge and banks; and
- the surrounding area in terms of development and activity such as housing, industry, and agriculture.

Scouting should be done routinely throughout the year. This will allow you to develop a familiarity with the site, and to witness subtle changes in plant and animal development. During a scouting visit, you will want to take note of several parameters, including:

- water temperature and clarity;
- pest presence;
- pest development and density; and
- infested areas—note the pests' desired habitat.

To scout effectively, you must determine when potential pest populations are present and monitor them. **Insect** and plant development are regulated by a number of factors, but time and temperature are critical.

Prevention

As a first line of defense, IPM programs work to manage aquatic sites to prevent pests from becoming a threat. Preventive control of aquatic pests has three major objectives:

1. Prevent the spread of pests.
2. Eliminate nutrient sources that support the pest.
3. Engineer habitats to be less desirable to the pest.

Preventing spread

Invasive plants can appear quickly even in isolated aquatic sites. Plant materials such as spores, seeds, or fragments can often be carried by the wind, water, animals, and human beings. People are primary movers of aquatic weeds and mollusks, transporting pests on boats, boat trailers, fishing waders, and on feet or clothing. People also contribute to the spread of aquatic weeds by disposing of aquarium plants into water bodies and by using such weeds to pack bait like worms or minnows. Many human activities that spread weeds can be easily prevented with education and sufficient monitoring. The following guidelines can help prevent the spread of aquatic weeds:

- Monitor and **eradicate** small, new infestations.
- Communicate with neighbors and other applicators about nearby weedy areas, infestation levels, and control practices. Communication can alert you to new weeds and help focus monitoring efforts. Early treatment can prevent large infestations. Cooperation in adopting similar prevention practices can reduce the spread of pests in your immediate surroundings.
- Make sure boats and other vehicles are cleaned thoroughly to prevent the spread of weeds or mollusks from one water system to another.

Boats and trailers can easily harbor aquatic pests in bilges, engine cooling systems, buckets, live wells, and anywhere else that water is trapped. The **Drain, Clean and Dry** procedure can help prevent your boat and others' from becoming **carriers** of invasive species.

Drain, Clean, and Dry

1. Drain
    - Drain every surface or space that could conceivably hold water.
    - Eliminate all water from your engine (follow factory guidelines).
    - Remove the drain plug from boats and put boat on an incline so that the water drains out.
    - Drain live wells, bilges, ballast tanks, and transom wells.
    - Empty water from kayaks, canoes, rafts, etc.
2. Clean
    - Remove all visible plant or animal fragments, along with mud or other debris.
    - Check your trailer, including the axle and wheel areas, in and around the boat itself.
    - Clean and check and dry off all parts and equipment that came in contact with water.
    - Empty bait buckets into trash. Do not empty any bait fish into the lake or reservoir.
    - Apply **potassium chloride** (**KCl**) over surfaces that have contacted water. This is an effective **molluscicide** that works on both adults and **veligers**. You should apply it as a 200 ppm **solution**; this is easily accomplished by mixing 1 teaspoon of dry KCl crystals with 2 gallons of water. This solution is not corrosive, and it is harmless to other aquatic organisms and to humans. KCl crystals are available in many home improvement stores.
    - Household salt will not kill zebra and quagga mussels.
3. Dry
    - Allow everything to dry completely before launching into another water body.

Follow this procedure EVERY TIME you use your boat, and especially before moving from one water body to another.

Nutrient management

The addition of nutrients from fertilizers and livestock manure can lead to huge increases in algae, plant, and mollusk productivity, which can in turn lead to increases in the vertebrate pests that feed on those organisms and the insect pests that take shelter in them. Such **nutrient loading** causes a lake or river's ecosystem to deteriorate rapidly; this process is called **eutrophication**.

Phosphorus (P), nitrogen (N), and carbon (C) are the nutrients of most concern. Each of these elements are required for plant growth, and overloading a system with them will cause intense algal blooms and large stands of aquatic plants. P and N often enter a system because of agricultural or lawn fertilizer runoff.

Physical and mechanical control

There are many methods of **mechanical** or physical aquatic pest control. Some of these are not feasible without proper equipment, sufficient labor, or money, but mechanical control can be effective while minimizing environmental contamination. These methods include both hand-pulling or raking and the use of mechanical equipment.

Hand pulling or raking can be quite effective for small stands of aquatic weeds, but it requires hard, heavy, stooping labor, and is extremely time consuming. Weeds may resprout from leftover material.

Harvesters cut rooted vegetation 4–6 feet below the water surface. They are primarily used on larger lakes or rivers. Most mechanical harvesters cut the vegetation and remove or harvest it from the water body. Timing of mechanical harvesting or cutting can be very important; at certain times of year, cutting will actually stimulate plant growth. Harvesting provides only temporary control and can be very costly.

Cultural control

Cultural control usually refers to ways of managing landscapes through crop and soil management, but in an aquatic context, we can simply call it **habitat alteration**. Cultural control methods in ponds, lakes, and streams include **shoreline alterations**, **winter drawdowns**, bottom covers or **benthic barriers**, dyeing, and **aeration**.

Shoreline alterations generally involve lining shorelines with rocks or other hard materials to prevent both erosion and the establishment of unwanted vegetation.

Winter drawdown means decreasing the water level in the lake or pond in order to expose shallow areas to freezing and drying conditions. This is effective for controlling many **submersed** and **rooted floating** weeds. Drawdown is usually accomplished with structures built to control water flow into the water body, the installation of siphoning systems, or naturally, as a result of low rainfall.

One benefit of **partial drawdown** is the concentration of fish in one small, deep area away from the shallow **weed** zone. Concentration enables larger fish to more effectively prey on small fish, and results in an overall improvement in fish quality. In addition, drawdown will dry and compact the exposed sediments, which will deepen the water body. Drawdowns tend to restructure the species composition of the lake ecosystem. Plants that are susceptible to drawdown include many of the pondweeds, waterlily, and watershield.

Increasing the water level in a pond may control emergent weeds by “drowning,” **free-floating** species by flooding or washout, and submerged species through light limitation because of the deeper water column. However, the killed plant material should be removed after this operation to prevent decomposition in the water.

Burning

Burning, in conjunction with cutting, winter drawdown, and **herbicide** use, can remove the aboveground parts of plants and may expose the **hydrosoil** to drying. In some cases, burning can reduce the viability of underground propagation tissue as well as seeds. Burning is a dangerous operation and should be undertaken only after sufficient safety measures have been put in place.

Other IPM methods

Bottom covers can also be part of an IPM program for aquatic sites. Materials like black plastic and specially manufactured benthic barriers can be used to shade out or prevent rooted aquatic weeds from growing or becoming established. These covers can be expensive, but are effective for specialized sites like ornamental ponds and swimming areas. They can be installed during construction or drawdown, and are usually weighted down with gravel or **sand**.

Black plastic does become brittle over time, so if a bottom cover with this material is present, be aware of any floating pieces of plastic that indicate deterioration, and replace or remove the barrier. Benthic barriers are useless once they become covered with sediment.

Dyeing with nontoxic dyes can inhibit submersed plant growth. The dye prevents sunlight getting to the plants and interferes with **photosynthesis**. While this may be beneficial in controlling aquatic weeds, it can also affect growth of desirable species. This is a very simple and easy control method to implement; the dye spreads easily in water and must simply be maintained throughout the season to control weeds. However, the use of dye is limited to water bodies with no outflow. Dyes must be applied early in the spring before weeds emerge and reach the surface of the water. Dyes used for aquatic weed control are pesticides and are subject to the same laws and regulations as any pesticide. Always follow the label in either case.

Aeration can improve aquatic environments by raising oxygen levels; however, its influence on aquatic weed growth may be good or bad depending on the characteristics of the particular site where it is used. Injection of air into lake bottoms draws algae into the deeper areas where limited sunlight slows their growth. However, injection may also disturb bottom sediments and release nutrients that increase weed growth. Improved **dissolved oxygen** (**DO**) levels from aeration may increase the magnitude of algal blooms, but not always. Each water body is different, and should be evaluated carefully before aeration.

Biological control

Biological control uses living organisms like insects, animals, and **pathogens** to control undesirable vegetation or insect pests. Biological control occurs naturally, but releasing more of a pest's natural enemies—**parasites**, **predators**, or disease agents—into the target area can increase this natural control.

Biological control agents are used in aquatic environments to control insects, mites, and some weeds. For example, the snout moth species *Acentria ephemerella* has been successfully used to control Eurasian watermilfoil. Biological control does not aim to eradicate pests, but to keep them at low, manageable levels as part of a balanced ecosystem.

Snout moth (*Acentria ephemerella*)[1]

Insect predators kill unwanted insects by direct attack. They usually prey on a large number of individuals to obtain sufficient food. Predators should not be mistaken for insect pests.

Parasites develop in or on a **host** and are detrimental to it. A parasite may or may not kill its host. A **parasitoid** is a type of parasite that develops as larvae in or on a host insect from eggs laid on, in, or near the host. Parasitoids usually kill their host by eating its body.

Pathogens are occasionally responsible for suppressing outbreaks of insect pests and weeds. These living disease organisms can spread through populations quite rapidly if conditions favor infection. Pathogens include fungi, bacteria, protozoa, and viruses.

For a biocontrol agent to be successful, it must be adaptable and voracious. **Selectivity** is very desirable, particularly among organisms feeding on emergent plants.

After their introduction, biocontrol agents can take 5–10 years to become established and increase to numbers large enough to reduce the density of the **target pests**. Once established, effective biological controls provide an inexpensive and long-term means to control weed populations.

It is important to match the biocontrol to the pest management site. All organisms have specific requirements for growing and thriving, and unforeseen problems can result when biological control agents are introduced into an ecosystem without proper planning. For example, the **herbivorous** grass carp (*Ctenopharyngodon idella*) was introduced to control aquatic weeds in many states, but its use is now prohibited or strictly monitored in many areas because it can devastate plant communities.

Grass carp (*Ctenopharyngodon idella*)[2]

Triploid grass carp (with three sets of chromosomes instead of the normal two) have been produced in hatcheries. They can be used as biocontrols more easily because they are sterile and will not increase in number. Care should be taken in choosing and stocking biocontrol agents; solicit the advice of a biologist knowledgeable about your watershed.

When you release biocontrols, continue using other control methods on the perimeter of the release site, but avoid using them where they might adversely impact the biocontrol population. Natural enemies can be highly sensitive to pesticides, and should be released in areas without disturbances or pesticide application.

Biological control agents are available from many government programs, which can also provide you with more information about regulations governing particular species. In Wyoming, call the Wyoming Game & Fish Department for more information.

Chemical control

In many cases, pesticides must be used to prevent harmful pest levels. Use pesticides only where they are needed and where they can be used safely. It is essential that pesticide applicators correctly identify the target species and follow the label directions regarding application and cleanup/disposal of the pesticide following use. If the target pest species is incorrectly identified, the pesticide may be ineffective. Using pesticides along with other methods is often better than using any one method by itself; however, relying on pesticides alone is rarely the best means of pest control. The methods chosen will depend on the kind and amount of control needed.

Pesticides are registered for the specific uses and application methods for which they have been tested. Uses other than those indicated on the label are unlawful and may not provide the needed control. Off-label use can adversely affect non-target species on- and off-site by drift or movement in soil and water. Furthermore, unauthorized use may pose a hazard to human health. Please note it is illegal to use higher rates of pesticide than are specified on the label, but you are permitted to use lower rates as long as the label does not prohibit it.

Again, because aquatic systems are so interconnected and so vital to human and animal welfare, it is especially important to understand the pesticide you are using when working in a water-dominated site.

Pesticides for use in aquatic systems can include herbicides, for vascular plants, **algaecides** for planktonic and **filamentous algae**, molluscicides for shelled aquatic animals, **insecticides** for nuisance insects, **piscicides** for fish, and **repellents** for large vertebrates.

ADDITIONAL RESOURCES

Aquatic and Riparian Weeds of the West. J. DiTomaso and E. Healy. University of California Agriculture and Natural Resources. 2003. *Provides information on weed identification, habitats, distribution, and control methods, with color photographs.*

National Pesticide Information Center (**NPIC**), Oregon State University. 800-858-7378. http://npic.orst.edu. 333 Weniger Hall, Corvallis, OR 97331-6502. *Information about pesticides and pesticide-related topics.*

United States Environmental Protection Agency's IPM website: https://www.epa.gov/safepestcontrol/integrated-pest-management-ipm-principles. *An overview of the IPM process, with links to more information.*

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education.* *See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos.* *See page 2.*

LAWS AFFECTING AQUATIC PEST MANAGEMENT

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Know the laws pertaining to pesticide application for your state and where to obtain them

B. Understand what quarantines and inspections are

C. Understand the major provisions of FIFRA

D. Understand the basic requirements of recordkeeping

E. Understand federal and state noxious weed laws

F. Describe how the Endangered Species Act relates to pesticides

INTRODUCTION

The laws presented in this chapter are the federal laws governing pesticide application. Each state has different laws that also govern pesticide application. You are responsible for knowing the particular laws and regulations for any state you may be working in. The following summarizes the laws governing pesticide application in each of our region's states. In most cases, you will be required to read and understand these laws and regulations in order to qualify for any pesticide applicator's license.

REGULATORY MEASURES

Regulatory measures are aimed at excluding, eradicating, or reducing plant pests. Inspections and quarantines are used to restrict the movement of plant material, plant products, or soil from an area with the pest to areas that do not have the pest. Generally, inspections are used to certify the absence of a pest before shipment or upon receipt of a shipment. Various agencies in your state may be responsible for inspections of plant material. Quarantines, sometimes called containment, are used to prevent the escape of a pest from a limited area. Quarantines prevent entrance of certain materials into an area. As an aquatic applicator, you may need to understand quarantines and inspections for **noxious weeds** or invasive invertebrates.

THE FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT

Under the **Federal Insecticide, Fungicide, and Rodenticide Act** (**FIFRA**), no one may sell, distribute, or use a pesticide unless it is registered by the **Environmental Protection Agency** (**EPA**). Registration includes approval by the EPA of the pesticide's label, which must give detailed instructions for its safe use. The EPA must classify each pesticide as either general use, restricted use, or both. **General use pesticides** may be applied by anyone, but **restricted use pesticides** may only be applied by **certified applicators** or persons working under the direct supervision of a certified applicator.

FIFRA distinguishes between commercial and private applicators. **Private applicators** use or supervise the use of pesticides on property owned or leased by them or their employers for the purpose of producing an agricultural commodity. **Commercial applicators** include all other certified applicators.

Labeling

Labeling is the basis for enforcement of FIFRA. FIFRA defines "label" as "the written, printed, or graphic matter on, or attached to, the pesticide or device or any of its containers or wrappers." FIFRA makes it unlawful to "use any pesticide in a manner inconsistent with its labeling." Thus, the pesticide applicator has a legal obligation to read and follow not only the label instructions attached to the product, but also all material to which the label refers. Failure to do so is a violation of FIFRA.

Supplemental labeling includes any information you receive from the manufacturer about how to use the product. Supplemental labeling is considered part of the pesticide label and may be supplied at the time of purchase or requested from the dealer. Supplemental labels include special local needs labels (Section 24c) which are only valid in the issuing State, and use information issued by the pesticide manufacturer. If an applicator applies a pesticide according to a supplemental label, a copy of the supplemental label must be in the applicator's possession at the time of application.

Penalties for misuse by commercial applicators

FIFRA makes provisions for both civil and criminal penalties for misuse by commercial applicators. Civil penalties cannot exceed $5,000 for each offense. A hearing on charges will be afforded in the county or city of residency of the applicator charged. Commercial applicators convicted of violating FIFRA are guilty of a misdemeanor and are subject to a fine of up to $25,000, one year in prison, or both. Commercial applicators are criminally liable for the acts of their employees.

Record keeping

Many states' pesticide application laws include **record keeping** provisions. Record keeping is an important part of any applicator's toolbox: it allows you to track sites and determine what works well and what does not. Check with your state to determine legal record keeping requirements.

TRANSPORTATION OF PESTICIDES

The **Federal Department of Transportation** (**DOT**) regulates shipment of pesticides and other dangerous substances across state lines. DOT issues the rules for handling these materials.

DOT standards tell you which pesticides are dangerous to human beings and create a health hazard during transportation. If you ever haul pesticides between states, you should know that:

- The pesticides must be in their original packages. Each package must meet DOT standards.
- The vehicle must have a correct sign. Manufacturers must put the correct warning signs on each package.
- The pesticides may not be hauled in the same vehicle with food products.
- You must contact DOT right away after each accident if someone is killed, someone is injured badly enough to go to a hospital, or when damage is more than $50,000.
- You must tell DOT about all spills during shipment.

Summary of state laws governing pesticide application

Colorado
- Colorado Pesticide Applicators' Act (CPAA): Colorado Revised Statutes 35:10 and Rules and Regulations Pertaining to the Pesticide Applicators' Act 8-CCR-1203-2; Colorado Noxious Weed Act 35:5.5
- www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1165692857751;
- www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1230899249850
- Pay special attention to posting requirements

Montana
- Montana Agricultural Pesticide Act; Montana Code Annotated 75-5-308; Montana Rules 4.10.311-4.10.317
- www.agr.mt.gov
- www.mtrules.org
- Pay special attention to the requirements for a management plan

North Dakota
- North Dakota Pesticide Act, Chapters 4-35 and 19-18 of the North Dakota Century Code
- https://www.nd.gov/ndda/pesticide-fertilizer-division/pesticide-program
- ND has no separate category for aquatic applicators

South Dakota
- South Dakota Codified Laws 38-20A and Administrative Rules of South Dakota 12:56, particularly 12:56:04:06 and 12:56:05:04.06
- http://legis.state.sd.us/index.aspx
- Pay special attention to the requirements for flagging

Utah
- Utah Pesticide Control Act R68-7
- www.rules.utah.gov/publicat/code/r068/r068-007.htm

Wyoming
- Wyoming Environmental Pesticide Control Act of 1973: Wyoming Statutes 35-7-351; Wyoming Applicator Certification Rules and Regulations
- http://agriculture.wy.gov/divisions/ts

NOXIOUS WEED LAWS

The Plant Protection Act

The **Plant Protection Act** (**PPA**) defines a noxious weed as a weed that could bring harm to agriculture, the public health, navigation, irrigation, natural resources, or the environment.

A list of noxious weeds that are prohibited from entering the U.S. or moving among States, except under a permit with restricted conditions, is currently available on the APHIS website at www.aphis.usda.gov. Any person may petition the Secretary of Agriculture to add or remove a plant species from this list.

THE ENDANGERED SPECIES ACT

Under the **Federal Endangered Species Act**, it is unlawful to "take" any animal listed as an **endangered species** by the United States Fish and Wildlife Service. "Take" is broadly defined to mean "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in such conduct." "Harm" has been defined as an action which actually kills or injures wildlife. Such actions may include significant habitat modification or degradation where the action kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Therefore, when using chemicals or altering land, you should be aware that your actions might affect endangered species or their habitat. Pesticides might injure or kill endangered species if allowed to drift onto habitat, and pesticide runoff into streams, lakes, or wetlands might be found to significantly degrade endangered wildlife habitat.

You should carefully read pesticide labeling for any reference to effects on endangered species habitat. You should also find out whether endangered species are present in the area to be treated or likely to be affected by treatment.

Bulletins are a part of EPA's Endangered Species Protection Program (ESPP). Bulletins set forth geographically specific pesticide use limitations for the protection of endangered or threatened species and their designated critical habitat. If your pesticide label directs you to the ESPP website (www.epa.gov/espp), you are required to follow the pesticide use limitations found in the bulletin for your county, pesticide **active ingredient** (ai), and application month.

Penalties under the Endangered Species Act are severe. Civil penalties of up to $25,000 for each violation and criminal penalties of up to $50,000, imprisonment for one year, or both may be assessed against a person who knowingly violates the Act. The Act also contains a citizen suit provision, which means that private citizens may sue the Secretary of the Interior to impose enforcement actions against a violator.

THE CLEAN WATER ACT

The Clean Water Act (CWA) of 1972 aims to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources, providing assistance to publicly owned treatment works for the improvement of wastewater treatment, and maintaining the integrity of wetlands.

Under the CWA, a permitting program for aquatic pesticide applications may be in effect at the time of this printing. You should check the status of this program in your state by contacting your state's Department of Agriculture.

ADDITIONAL RESOURCES

Environmental Protection Agency. Ariel Rios Building, 1200 Pennsylvania Avenue, N.W., Washington, DC 20460. Phone: 202-272-0167. www.epa.gov. *Information on Federal laws designed to promote public health by protecting air, water, and soil from pollution.*

Environmental Protection Agency Clean Water Act. https://www.epa.gov/laws-regulations/summary-clean-water-act. *Information on the Clean Water Act.*

Environmental Protection Agency Endangered Species Protection Program. https://www.epa.gov/endangered-species. *Information on the Endangered Species Act.*

National Agriculture Compliance Assistance Center. 901 N. 5th Street, Kansas City, KS 66101. Phone: 888-663-2155. www.epa. gov/agriculture. *Information about environmental requirements that affect the agricultural community.*

North American Weed Management Association (NAWMA). P.O. Box 1910, 461 E. Agate, Granby, CO 80446-1910. Phone 970-887-1228. www.naisma.org. *A network of public and private professional weed managers who are involved in implementing any phase of a county, municipal, district, state, provincial or federal noxious weed law.*

U.S. Fish and Wildlife Service Endangered Species Program. https://www.fws.gov/endangered/. *Information on the Endangered Species Program.*

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education.* *See page 1.*

State Pesticide Safety Education Programs.

These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos. *See page 2.*

USING PESTICIDES SAFELY

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Define the terms label and labeling

B. Recognize the parts of the label and understand that the label is a legal document

C. Know what a SDS is and understand what information is located on a SDS

D. Describe why pesticides must be handled carefully

E. Understand basic toxicity terms

F. Know the routes of pesticide exposure (dermal, oral, inhalation)

G. Know how to avoid pesticide exposure

H. Know how to select, correctly wear, and maintain work clothing and personal protective equipment

I. Be aware of signs and symptoms of pesticide poisoning

J. Know how to be prepared to safely and effectively respond to pesticide emergencies

K. Know how to safely store pesticides

L. Know how to be prepared for a spill

M. Know how to dispose of pesticide containers and pesticides safely and legally

INTRODUCTION

There are two great reasons to use pesticides safely:

1. to keep yourself and others from being poisoned, and
2. to avoid harming the environment.

Pesticides are toxic and can cause injury. You should be thoroughly trained in the uses and hazards of the materials you are using. You are responsible for preventing damage to the public, to property, to the environment, and to yourself and other applicators. In addition, the application must achieve effective results on the weed or pest problem you are treating.

LABELS AND LABELING

Each time you buy a pesticide, you receive instructions to tell you how to use it. The pesticide label describes the risks and benefits of the pesticide product to the user, but it is also the primary tool of pesticide regulation. The combined knowledge of many people in industry, universities, and government is used to develop the information on the label. This information will tell you how to use the product safely and correctly.

Labeling is all the information that you receive from the company or its agent about the product. Labeling includes such things as the label on the product, brochures, flyers, and information handed out by your dealer. It must not differ in meaning from the information furnished to EPA when the product was registered.

The time you invest in reading the label is probably the most valuable few minutes you can spend in pest control. This small investment in time will help you avoid injuring yourself, harming the environment, or breaking the law by misusing the pesticide.

The label has different functions for each person who uses it:

- To the manufacturer, the label is a license to sell.
- To the state or federal government, the label is a way to control the distribution, storage, sale, use, and disposal of the product.
- To the dealer and user, the label indicates whether the pesticide is for restricted or general use, and whether certification is required.
- To the buyer or user, the label is the main source of facts on how to use the product correctly and legally. It is a way to tell users about special safety measures needed.
- To dealers and pest control experts, the label is an aid in making recommendations to buyers and users.
- To medical personnel, the label is a way to determine what antidote or **first aid** procedure to use in the treatment of poisoning cases.

Parts of the label

Some labels are easy to understand, while others are more complicated. Federal regulations require certain information to appear in certain locations on the label. This is known as format labeling. The concept of format labeling was developed to help you read the label. If you know where to look on labels for specific kinds of information, you can better understand the correct use of the pesticide. The fictitious label is numbered; each number corresponds to a section in the following table that explains each specific part. (See previous pages.)

DIRECTIONS FOR USE BY REFERENCE

In addition to label directions, pesticide users must also obey directions contained in documents that are only referred to on the product labeling. This practice has become necessary because there is no longer room on the traditional label to explain the requirements of all laws and regulations. A referral might say: "Use of this product in a manner inconsistent with the PESTICIDE USE BULLETIN FOR PROTECTION OF ENDANGERED SPECIES is a violation of Federal laws. Restrictions for the protection of endangered species apply to this product. If restrictions apply to the area in which this product is to be used, you must obtain the PESTICIDE USE BULLETIN FOR PROTECTION OF ENDANGERED SPECIES for that county." This statement would probably be the ONLY indication in the labeling material that other use directions and restrictions apply to the product.

You are responsible for determining whether the regulation, bulletin, or other document referred to on the pesticide or product labeling applies to your situation and your intended use of the product. If the document is applicable, you must comply with all the specific directions for use and other requirements that it contains. These documents do not always accompany the pesticide product when it is sold. Instead, you may have to get the additional directions and requirements from other sources, such as EPA's website, pesticide dealers or company representatives, industry or commodity organizations, land-grant universities, or your county extension educator.

Misuse statement

This section on the label will remind you that it is a violation of Federal Law to use a product in a manner inconsistent with its labeling. Do not use a product on a site not listed on the label. Do not use it at more than the recommended rate. Before the product can be registered, EPA requires the manufacturer to conduct many tests to be sure the label directions are correct. By following them exactly, you will get the best results the product can give and avoid breaking the law.

No pesticide may legally be used or recommended in any way that conflicts with the recommendations on the registered label. Illegal uses or recommendations are any that:

- increase the rate of application over the maximum shown on the label,
- change the method, time of application, or other conditions of use shown on the label, or
- include a site or crop to be treated that is not shown on the label.

However, it is not illegal to use a pesticide:

- at rates less than those recommended on the label,
- for a pest unnamed on the label if the site of application is listed on the label,
- in combination with fertilizers, or
- in combination with other pesticides, providing that labeled rates for each pesticide are not exceeded and the combination of products is not prohibited by any of the pesticide labels.

Reentry statement

If required for the product, this section on the label will tell you how much time must pass before a pesticide-treated area is safe for entry by a person without protective clothing. Carefully observe restricted-entry intervals (REI) to avoid unnecessary exposure and possible poisoning. Consult local authorities for special rules that may apply.

Waiting periods/use restrictions

If required for the product, this section will tell you how much time must pass between pesticide application and water use or water-based activities such as swimming and fishing.

Category of applicator

If required for the product, this section will limit use to certain categories of commercial applicators.

When to read the label

Read the label before buying the pesticide to determine:

- If this is the chemical you need for the job—never depend on the color of the label or on the product name when you purchase or select a pesticide. Labels of the same color and general makeup may contain different active ingredients.
- If this material is too toxic or hazardous to be used safely under your conditions.
- The concentration in percent or pounds per gallon of active ingredient.
- If the formulation is suitable for your equipment.

Read the label before mixing and applying the pesticide to determine:

- necessary PPE for safe handling,
- warnings and antidotes, when required,
- what you can mix with it,
- how much to use,
- rate of application,
- restrictions of use, and
- special instructions.

Read the label before storing or disposing of pesticides and containers to determine:

- where and how to store,
- where it should not be stored,
- what it should not be stored with,
- how to decontaminate and dispose of the container, and
- where to dispose of leftover pesticides or empty containers.

Carry the label with you

Whenever a pesticide is applied, the original product container with labeling or a copy of the

THIS FICTITIOUS LABEL IS FOR EDUCATIONAL PURPOSES ONLY

1 RESTRICTED USE CLASSIFICATION

Due to acute toxicity. May injure (phytotoxic) susceptible, non-target plants.
For retail sale to and use only be Certified Applicators or person under their direct supervision, and only for those uses covered by the Certified Applicators Certification.

2 AQUA-KLEER

Herbicide

3 ACTIVE INGREDIENTS:
Butoxyethyl ester, 2,4,
Dicholorpheoxyacetic acid 44.8%
OTHER INGREDIENTS:. 55.2%
TOTAL 100.0%

KEEP OUT OF REACH OF CHILDREN

4 DANGER/POISON

5 EPA REG. NO. 34890-86

6 EPA EST. NO. 34890-CL-9

[redacted]

If swallowed: Call poison control center or doctor for treatment advice. Do not induce vomiting.

If in eyes: Flush with plenty of water. Call a physician if irritation persists.

If inhaled: Remove victim to fresh air. If not breathing, give artificial respiration, preferably by mouth. Call poison control center or doctor for treatment advice.

[redacted]

HAZARDOUS TO HUMANS AND DOMESTIC ANIMALS

DANGER/POISON: May be fatal if swallowed. Fatal if inhaled. Causes substantial but temporary eye injury. Harmful if absorbed through skin.

Personal Protective Equipment (PPE)
Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Shoes plus socks
- Protective eyewear
- Waterproof gloves
- Respirator

Discard clothing and other absorbent materials that have been drenched or heavily contaminated with this product's concentrate. Do not reuse them.

ENVIRONMENTAL HAZARDS
This product is toxic to fish. Drift or runoff may adversely affect fish and non-target plants. Do not apply to water except as specified on this label. Do not contaminate water when disposing of washwater.

[redacted]

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

Use AQUA-KLEER as a broadcast or spot treatment at rates of 1/4 to 2 quarts per acre to control broadleaf weeds, woody plants, and vines. AQUA-KLEER may be tank mixed with Harpo 3 Herbicide, 3,4-D amines or low-volatile esters. Total use of AQUA-KLEER must not exceed 2 quarts per acre per annual growing season on aquatic sites. Avoid contact with the foliage of non-target or desired plants.

This product may have effects on endangered species. When using this product, you must follow the measures contained in the Endangered Species Protection Bulletin for the county in which you are applying the product. To obtain Bulletins consult www.epa.gov/espp, or call 800-447-3813 no more than six months before using this product. You must use the Bulletin valid for the month in which you will apply the product.

Treatment of dense weeds may result in oxygen loss from decomposition, which may cause fish suffocation. Therefore, treat only 1/3 to 1/2 of the water body at one time and wait 14 days between treatments.

WATER USE RESTRICTIONS: Potable water 3 days; Livestock 1 day; Irrigation non-crop 3 days; Irrigation crop 5 days.

[redacted]

Do not contaminate water, food, or feed by storage or disposal.

STORAGE: Store in safe manner. Keep pesticide in original container only. Keep container tightly closed when not in use. Personnel should use clothing and equipment consistent with good pesticide handling.

PESTICIDE DISPOSAL: Wastes resulting from the use of this product may be disposed of at an approved waste disposal facility.

CONTAINER DISPOSAL: Completely empty bag into application equipment. Then dispose of empty bag in a sanitary landfill. Do not reuse container.

Parts of the example "AQUA-KLEER" label		
Location	**Label Part**	**Description**
1	Statement of Use Classification	Federal Restricted Use Products (RUPs) are required to have a statement indicating the use classification and also a statement of why the pesticide is classified as a RUP.
2	Brand Name	Brand (trade) name used by a manufacturer to identify a pesticide as its product.
3	Ingredient Statement	Identifies the name and percentage by weight of each active ingredient. The ingredient statement must list the official **chemical names** and/or common names for the active ingredients. **Inert ingredients** need not be named, but the label must show their percentage of the total contents.
4	Signal Words	Indicate approximately how toxic the pesticide product is. Products that are highly toxic must display on the label the signal words **DANGER-POISON** along with a skull and crossbones symbol. Products that display only the signal word **DANGER** are **corrosive** and can cause irreversible eye damage or severe skin injury. Products that display the signal word **WARNING** are moderately toxic or can cause moderate eye or skin irritation. Products that display the signal word **CAUTION** are slightly toxic or may cause slight eye or skin irritation.
5	EPA Registration Number	Shows that the product has been registered with the EPA and may be legally sold and applied according to label directions.
6	EPA Establishment Number	Identifies the establishment or facility where the pesticide was manufactured
7	Statement of Practical Treatment	Lists the first aid treatment that should be administered to someone accidentally exposed to the pesticide.
8	Precautionary Statements	Identify potential hazards and recommend ways that the risks can be minimized or avoided. Types of precautionary statements include: • Hazards to Humans (and Domestic Animals): Indicates the ways in which the product may be poisonous to human beings and animals and any special steps you need to take to avoid poisoning. • Environmental Hazards: Explains potential hazards and precautions needed to prevent injury or damage to nontarget organisms or to the environment. • Physical and Chemical Hazards: Lists any special fire, explosion, or chemical hazards that the product may pose.
9	Directions for Use	Begins with the statement, "It is a violation of Federal law to use this product in a manner inconsistent with its labeling." Tells you: • the pests which the manufacturer claims the product will control, • the crop, animal, or site the product is intended to protect, • when, where, how, and in what form the product should be applied • the proper equipment to be used, • the correct dosage, mixing directions, **compatibility** with other often-used products, minimum time between the application and entry into the treated area for unprotected persons, • possible plant injury (phytotoxicity) problems, and • Endangered Species Protection requirements.
10	Storage and Disposal Directions	Indicates how to store and dispose of the pesticide and empty containers.

pesticide label and labeling of the product(s) in use should be in the possession of the applicator at the site of application. If an applicator applies a pesticide according to a supplemental label, a copy of the supplemental label should be in the applicator's possession. Check with your state for specific requirements.

READING AND UNDERSTANDING THE SAFETY DATA SHEET (SDS)

A **Safety Data Sheet** (SDS) (formerly known as the Material Safety Data Sheet, or MSDS) is a technical bulletin which provides workers and emergency personnel with the proper procedures for handling or working with that substance. The SDS communicates information vital to the safe use and handling of each chemical or product. The SDS includes information such as physical data (i.e., melting point, boiling point, flash point, etc.), toxicity (i.e., LD50), health effects, first aid,

Safety Data Sheet Organization	
The SDS should answer:	**Location on SDS**
What is the material and what do I need to know IMMEDIATELY in an emergency?	Section 1. Chemical Product and Company Identification Section 2. Composition, Information on Ingredients Section 3. Hazard Identification
What should I do if a hazardous situation occurs?	Section 4. First Aid Measures Section 5. Fire Fighting Measures Section 6. Accidental Release Measures
How can I prevent hazardous situations from occurring?	Section 7. Handling and Storage Section 8. Exposure Controls, Personal Protection Section 9. Physical and Chemical Properties Section 10. Stability and Reactivity
Is there any other useful information about this material?	Section 11. Toxicological Information Section 12. Ecological Information Section 13. Disposal Considerations Section 14. Transport Information Section 15. Regulatory Information Section 16. Other Information

reactivity, storage, disposal, protective equipment, and spill/leak procedures. The SDS is available from the pesticide manufacturer or supplier and supplements the information provided on labels. The SDS also provides contact details for further information on the pesticide.

The Occupational Safety and Health Administration (OSHA) requires that:

- Employers must maintain copies of the required SDS for each hazardous chemical in the workplace.
- Employers must ensure that the SDS are readily accessible to personnel.
- Personnel must be able to interpret and apply the information presented in the SDS.

Organization of the SDS

The section titles and their order are the same from manufacturer to manufacturer, but the given information within each section is left to the discretion of the manufacturer.

TOXICITY AND HAZARD

Pesticides are toxic and cause injury. Toxicity is not the only factor that determines how dangerous a chemical is to human beings or other animals. Anyone who handles pesticides should also be concerned with the hazard of the chemical.

The terms toxicity and hazard do not mean the same thing. Toxicity is the capacity of a substance to produce injury or death. Hazard includes two factors—toxicity and exposure. It is the possibility that injury will result from the use of a substance in a given formulation, quantity or manner. Hazard can be expressed as an equation:

Hazard = toxicity × exposure

Some hazards do not involve toxicity to humans or other animals. For example, many chemicals are considered safe or relatively safe to animals but may be phytotoxic because they pose considerable hazards to some plants.

A pesticide may be extremely toxic but present little hazard to the applicator or others when used:

- in a very dilute formulation,
- in a formulation that is not readily absorbed through the skin or readily inhaled,
- only occasionally and under conditions to which human beings are not exposed, and
- only by experienced applicators who are properly equipped to handle the chemical safely.

Or, a chemical may be low in toxicity but present a hazard because it:

- is normally used in a concentrated form,
- is rapidly absorbed or inhaled, and
- may be used by untrained persons who become exposed to it.

Acute vs chronic toxicity

Immediate or **acute toxicity** is the result of an accidental or intentional single or repeated short term exposure to a substantial dose of toxicant. The signal word on the label reflects the acute toxicity of the pesticide.

Long-term or **chronic toxicity** is the result of a prolonged or frequently repeated exposure to lower toxicant doses. Chronic effects are not generally observable immediately following exposure and signs or symptoms often appear only after a very long period of time.

LD_{50} and LC_{50}

The terms LD_{50} and **LC_{50}** are used to express the toxicity of a pesticide. LD means lethal dose. LD_{50} is the dose that will kill 50% of a large population of test animals. LC means lethal concentration. LC_{50} is the concentration in the air or water that will kill 50% of the test animals. The lower the LD_{50} or LC_{50} value, the more poisonous the pesticide. Oral and dermal LD_{50} values for a given material may be quite different.

Toxicity values can be expressed as an acute oral or acute dermal LD_{50}, in terms of milligrams per liter of water, milligrams per kilogram of body weight, micrograms of mist or dust per liter of air, or **parts per million** (ppm) by volume of gas or vapor.

Chronic poisoning is the result of prolonged exposure to small amounts of a pesticide. Acute LD_{50} values do not reflect the chronic toxicity of pesticides.

HOW PESTICIDES ENTER THE BODY

A pesticide can enter the body via three common routes:

1. dermal—**absorption** through the skin or eyes (ocular),
2. oral—absorption through the mouth and stomach, and
3. inhalation—absorption through the lungs

Dermal

Dermal exposure is the most common route of pesticide exposure for applicators. Generally, dermal exposure can be caused by accidentally spilling or spraying a pesticide directly on the skin. Exposure may also be caused by wearing clothing on which a pesticide has been spilled, or by drift of pesticides applied under windy conditions. If a pesticide is spilled on your clothing, immediately remove it and wash skin with soap and water. Dispose of the contaminated clothing.

In general, wettable powders, **dusts**, and **granular** pesticides are not as readily absorbed through the skin and other body tissues as are the liquid formulation such as **emulsifiable concentrates**. Emulsifiable concentrates contain a high percentage of the active ingredient in a relatively small amount of solvent. The solvents are readily absorbed through the skin.

If you have repeated or prolonged exposure to pesticides, take all precautions to avoid personal contamination. Wear protective clothing and safety devices prescribed by the manufacturer on the label, and follow recommended procedures for mixing and applying the chemicals.

Oral

Oral exposure results when a pesticide comes into contact with your mouth. When working with pesticides, wash thoroughly before eating, drinking, smoking, or using the toilet. To prevent children or other uninformed persons from accidentally drinking a pesticide, do not store pesticides in anything other than the original containers, such as soft drink bottles or other beverage or food containers.

Inhalation

Inhalation exposure is pesticide absorption through the lungs. It is the most rapid and efficient route by which pesticides enter the body. Vapors and very fine particles represent the most serious potential for inhalation exposure. Respirators protect against inhaling chemicals. They should be worn when handling or applying highly toxic pesticides. The label will indicate if a respirator is necessary.

Personal Protective Equipment (PPE)

Because pesticides can enter your body through various routes, it is essential that you wear a protective barrier of clothing called Personal Protective Equipment (PPE). No safety recommendations cover all situations; use common sense and remember that you need to take more protective precautions as the hazard increases. Always read the pesticide label for directions about the use of PPE or devices.

Be sure that you know how to use PPE correctly. Put on and remove this equipment carefully so that you do not come into contact with any pesticides on the outside of it. Do not "cheat" on PPE by taking off your gloves to make an equipment adjustment or by pulling your respirator away to scratch your face, wipe off sweat, or take a deep breath while you are still being exposed to the pesticide. Do not wipe your gloves on your clothing; this will contaminate your clothing and the pesticide may move through to your skin.

When working on the water in warm temperatures, you may be tempted to wear shorts or short-sleeved shirts. Remember that unclothed parts of the body can be directly exposed to pesticides, and the most common route of pesticide exposure for applicators is dermal. PPE is the most effective way to ensure that you are protected.

Avoiding pesticide exposure

The key to personal safety when handling pesticides is to avoid exposure. Always keep personal clothing, food, drinks, chewing gum, tobacco products, and other belongings away from where pesticides are stored or handled. They could become contaminated and poison or injure you when you use them.

When you take a break, wash your gloves on the outside, remove your gloves, and wash your face and hands thoroughly. Then you can safely chew gum, eat, drink, smoke, or use the restroom.

Avoid getting pesticide on yourself when you use the restroom. The skin in the genital area absorbs pesticide more readily than any other area.

Be careful not to contaminate yourself with pesticides that may be on the outside of your clothing.

Be aware of other situations where you might be exposed to pesticides on the job. Protect yourself not only during mixing, loading, and application, but also during spill cleanup, while repairing or maintaining equipment, and when transporting, storing, or disposing of pesticide containers that are open or have pesticides on their outer surfaces. Use PPE when necessary to keep pesticides from getting on your skin, and in your mouth, eyes, or lungs.

Be aware that unique situations may arise when you are in a boat or operating pesticide application equipment around water:

1. Your working surface may not be stable if there are waves on the water. Formulations may spill if left in open-topped containers when it is windy and the boat is rocking.
2. Boats may have seats or other surfaces that are covered in fabric, which can absorb pesticide spills and expose others to the pesticide. Proper and thorough cleanup is especially important in these situations.
3. Pesticide containers may fall into water or over the edge of the boat. NEVER dive in after a pesticide that was in an open or paper container, as you may become exposed to the pesticide as it dissipates from the container. Wear full PPE to retrieve the container.

PESTICIDE POISONING

Be aware of the general **signs** and **symptoms** of pesticide poisoning. Symptoms of poisoning are feelings noticed only by the person who has been poisoned, such as nausea or headache. Signs of poisoning, such as vomiting, are those results of poisoning that can be noticed easily by others.

The most common signs and symptoms from ingesting a herbicide or an insecticide are irritation of the mouth and throat, vomiting, chest and abdominal pain, and diarrhea. Skin and eye exposure usually result in irritation. Inhalation can cause coughing, dizziness, nose and throat irritation, and sometimes nosebleeds. All of these symptoms will not necessarily occur after excessive exposure. Differences occur between individuals, the amount and type of pesticide, and route of entry.

Not all pesticides cause the same symptoms and signs of illness. Each chemical family (such as bipyridiliums) attacks the human body in different ways. The sickness may be mild or severe, depending on the pesticide and the amount absorbed. Patterns of illness caused by one family of pesticides are similar, and are called **shared mechanisms of toxicity**. Also, laboratory tests are often helpful in identifying pesticide poisoning.

A breakdown of some of the basic properties of some chemical pesticides, how they may enter the body, and a description of symptoms of poisoning from each is found in the table on page 27.

FIRST AID

Seek medical help

First aid is just that: the initial effort to help a victim while medical help is on the way. It is essential in any poisoning emergency to get professional care for the victim as soon as possible, either by transporting the victim to an emergency care facility or by calling a physician. When professional help is not available, you must see that the victim continues to breathe and is not further exposed before leaving to make your phone call. Always save the pesticide and the label for the doctor's inspection.

First aid procedures

Read the directions in the First Aid or Statement of Practical Treatment on the label. These instructions can save your life and the lives of your employees and peers.

If you get a pesticide on your skin, remove the pesticide as quickly as possible. Remove all contaminated clothing.

Prompt washing may prevent sickness even when the spill is very large. Do not forget your hair and fingernails. Water-wettable powders or **suspensions** are easy to remove with plain water. So are most emulsifiable concentrates and **emulsions**. Solutions of pesticides in petroleum oil or other solvents are harder to remove without soap or a detergent. Detergents work better. Washrooms

IN AN EMERGENCY CALL

Poison Help Line

1-800-222-1222

www.aapcc.org

Local poison centers

Colorado and Montana
Rocky Mountain Poison and Drug Center
777 Bannock Street
Mail Code 0180
Denver, CO 80204
www.rmpdc.org

North Dakota and South Dakota
Hennepin Regional Poison Center
Hennepin County Medical Center
701 Park Avenue
MC-RL
Minneapolis, MN 55415
www.mnpoison.org

Utah
Utah Poison Control Center
585 Komas Drive, Suite 200
Salt Lake City, UT 84108
www.utahpoisoncontrol.org

Wyoming
Nebraska Regional Poison Center
8401 West Dodge Road, Suite 115
Omaha, NE 68114
www.nebraskapoison.com

Signs and Symptoms of Poisoning				
Pesticide	**Inhalation**	**Eyes**	**Dermal**	**Ingestion**
Copper compounds	Cough Sore throat	Redness Pain	Redness Pain Blurred vision	Abdominal pain Burning sensation Diarrhea Nausea Shock or collapse Vomiting
Bipyridyliums, including **diquat**	Burning pain in the mouth, throat, chest, upper abdomen. Nervousness, irritability, restlessness, combativeness, disorientation, nonsensical statements, inability to recognize friends or family members, diminished reflexes. Intense nausea, vomiting and diarrhea may occur.			
Chlorophenoxys, including **2,4-D**	Abdominal pain, burning sensation, diarrhea, headache, nausea, unconsciousness, vomiting, weakness.			
Dichlobenil		Blurred vision	May be absorbed and cause dry skin	Abdominal cramps Diarrhea Nausea Unconsciousness Vomiting
Endothall	Corrosive to the gastrointestinal tract. Cardiomyopathy and vascular injury leading to shock. Central nervous system injury, causing convulsions and respiratory depression.	Irritation	Irritation	Hemorrhage and edema of the gastrointestinal tract and lungs were observed in one case of severe poisoning.
Fluridone	Irritation	Irritation	Irritation	Low occurrence of symptoms via ingestion
Glyphosate	Cough. (See ingestion)	Redness	Redness	Diarrhea Shortness of breath Vomiting Weakness
Imidazolinones	Tremors, convulsions, salivation, diarrhea, coma, hypoactivity			
Antimycin	Has not been shown to be toxic in humans.			
Rotenone	Confusion Cough Headache Labored breathing Nausea Sore throat Unconsciousness Tremor	Redness	Redness	Abdominal cramps Convulsions Diarrhea Vomiting

and emergency field washing facilities should have detergents rather than plain soap.

If you inhale a pesticide, get to fresh air right away. If you splash a pesticide into your mouth or swallow it, rinse your mouth with plenty of water. Contact a poison center and go or have someone take you to a physician immediately. It is sometimes dangerous to induce vomiting; follow label directions.

Following eye exposure, flush the eyes with running water for several minutes and seek medical help.

Poison Information Center

Poison Information Centers are equipped to provide up-to-date information on cases involving all poisons, including pesticides. They are staffed 24 hours per day, every day of the year. This number is universal for all the states in our region.

PESTICIDE STORAGE

Store pesticides and pesticide mixtures in a manner which will prevent the contamination of other products. **Volatilization**, leakage, breakage, and other problems can cause contamination. Pesticides should be placed in well marked, well ventilated storage areas, and kept at temperatures that are not extreme (40°—100°F). Storage areas should be kept clean and orderly and should be locked to prevent unauthorized persons from entering. Warning signs should be placed on doors of chemical storage areas. Your state may have specific requirements for the wording of these signs.

Container lids should be securely tightened, and the containers placed on storage shelves after use. Pesticides must be kept in their original containers with the original label attached. Never transfer pesticides into soft drink bottles, water bottles, etc.

Incoming pesticides should be inventoried, checked for damage and leaks, and promptly placed in the proper storage location. Broken and leaking containers should be removed immediately, and the faulty containers disposed of properly.

As a pesticide applicator, you need to pay particular attention to your storage areas in regard to pesticide security. Pesticide products could be used intentionally to harm citizens; therefore, you must take precautions to safeguard and secure all pesticide products.

PESTICIDE SPILLS

Pesticide spills can pose serious threats to human health and cause significant environmental contamination. A thorough knowledge of the appropriate steps to take in the event of a spill will allow you to minimize the potential for adverse effects and may save you a great deal of money in cleanup costs. Always be prepared to handle spills before they occur. It is a good idea to have a spill kit in storage and mixing areas. Contamination can increase greatly if there is any delay in your response to a pesticide spill.

Spills may be relatively minor, involving one or a few leaking containers. However, major spills, like the overturning of a truck or sprayer, do occasionally occur. Regardless of the magnitude of the spill, the objectives of a proper response are the same. First, you must *control* the spill; second, you must *contain* the spill; third, you must *clean it up*. These three steps are frequently referred to as the "Three C's" of spill management.

In the event of an emergency or spill, CHEMTREC provides information on hazardous materials to local emergency responders and links them with the shipper, product manufacturer, or other expert resources that can supply technical information, product disposition guidance, or other assistance on how to successfully handle the incident. CHEMTREC's primary mission is to provide this and other vital information quickly and accurately 24 hours a day. *In the event of a spill call: 1-800-262-8200*. There is no charge to the caller for this service.

The Three C's of Spill Management

Control it

Contain it

Clean it up

PESTICIDE DISPOSAL

It is extremely important to dispose of your pesticide wastes responsibly, to protect water sources, animal habitat, and human health.

Rinsates

Improperly disposed **rinsates** from application equipment have great potential for causing ground and **surface water** contamination. Do not bury or discharge rinse water to the ground, septic systems, or ditches or streams. To minimize disposal, spray rinsates on the target area just treated or to other areas listed on the product label, if **application rates** and amounts will not be exceeded and if allowed by product label restrictions. If you are doing a series of applications using the same formulation, reuse the rinsate to dilute the next batch.

Leftover spray solutions

The way to "dispose" of excess spray solutions is to use all of the mixed pesticide in accordance with label instructions. Make sure that application rates and amounts are not exceeded. Avoid the problem of excess mixture by measuring and calibrating carefully. Fill your spray tank with only the amount required to do the job.

Excess pesticide product

Assuming you have the pesticide product in the original, properly labeled container that is no longer needed, you may use the product up according to the pesticide label on the container or contact other possible users of the pesticide to see if they have a need for it. Do not give RUPs to people who are not certified to apply them.

Banned pesticides

Assuming you have a pesticide product in the original, properly labeled container that is no longer legal to use, you may check to see if there is a recall program for your pesticide. If the pesticide registration was recently canceled, there may be a recall program available. The pesticide registrant may collect the pesticide for disposal.

Pesticide Collection Programs

Colorado
Colorado Chemsweep
888-AGCHEM2
https://www.colorado.gov/pacific/cdphe/hazardous-waste-management-agricultural-pesticide-collection-program
Provides pesticide pickups when you call, for a fee.

Montana
Pesticide Disposal Program:
(406) 444-5400
https://agr.mt.gov/Pesticide-Waste-Disposal-Program
Provides pesticide pickups once per year at one location. You must preregister.

North Dakota
Project Safe Send
800-242-7535
https://www.nd.gov/ndda/Programs/Plant/PSS.html
Rotating collection sites in summer.

South Dakota
Waste Pesticide Program:
(605) 773-4432
https://sdda.sd.gov/ag-services/pesticide-program/pesticide-collection-program/
Must preregister with form or online.

Utah
Pesticide Disposal Program
(801) 538-7188
https://ag.utah.gov/pesticide-collection-registration/
Registration form and contact information available on website.

Wyoming
(307) 777-7324
No specific program exists in Wyoming

If it is legal, use the product up according to the pesticide label on the container. Pesticides for which the labeled uses have changed or pesticides that have been taken off the market can usually be used until supplies are exhausted. For most pesticides that you have had for a number of years, you can legally use up the pesticide according to the pesticide label. However, there are exceptions to the rule—for some pesticides, EPA allows old label uses for only a short time after a product cancellation or label change. In rare cases, EPA may issue a "stop use" on a product at the time of its cancellation. Contact the pesticide manufacturer to find out whether you can still use a particular product.

Excess pesticide and rinsates that cannot be used must be disposed of as **hazardous waste**. One option to dispose of unwanted, unused, banned, or outdated pesticides is to utilize your state's pesticide waste collection program.

EMPTY PESTICIDE CONTAINERS

Proper rinsing and handling of empty pesticide containers is very important because it:

- protects humans by removing hazardous materials,
- prevents sources of environmental contamination,
- saves you money by putting all the product into the spray tank, and
- makes recycling or disposal of clean containers convenient and inexpensive.

Mishandled empty pesticide containers can create a major problem for you since most unrinsed containers are considered hazardous waste, complicating disposal. Before they are rinsed or cleaned, pesticide containers can still hold enough material to harm you or the environment. When emptying or cleaning containers, wear label required PPE. Be sure to protect your eyes and hands. Wear chemical-resistant gloves that will neither absorb pesticides or rinse water, nor let the material contact your skin. Wear goggles or a face shield that will protect your eyes from splashes or dust. You also may need to wear a respirator for protection from dust or fumes.

The rinse water from the container should be applied to the application site or to another labeled site at or below labeled rate. This is the safest way, both for you and the environment. It also creates less waste and therefore reduces cost. Do not dump rinse water on the ground.

General container handling guidelines

- Never abandon empty containers. Uncleaned containers can be very dangerous to people, animals, and the environment. Abandoning containers, even cleaned ones, is against the law.
- Burial of empty, uncleaned containers or unused product is not a safe practice. Even small amounts of pesticide can reach water supplies or contaminate the soil.
- When mixing, add container rinse water to the spray mix to avoid disposal problems.
- When purchasing pesticides, think about how you will dispose of the container. Manufacturers are putting more products in water soluble packages or in easily recycled containers to assist you in avoiding disposal problems and costs.

Metal or rigid plastic pesticide containers

Unless the pesticide label directs you otherwise, **triple rinse** containers or use pressure rinsing to clean them. Do not forget to completely rinse the hard-to-get-to areas inside the containers, such as the handle. Make sure you also rinse the outside of all containers.

Triple-rinse procedure

1. Empty as much of the pesticide into the sprayer as possible. Turn containers that are 5 gallons or smaller upside down over the spray tank and let them finish draining for at least 30 seconds after they stop

dripping. Pump or drain larger containers as empty as possible.

2. Add water or the mixing liquid to fill the empty container about ¼ full.
3. Shake smaller containers thoroughly. Add the rinse water to larger containers so that it contacts all of the inside surfaces.
4. Drain the container completely by holding it over the spray tank or pumping out the liquid. Add this rinse water to the spray tank if at all possible.
5. Repeat this process at least 2 more times, until the container is clean. When triple rinsing will not sufficiently clean the container, keep rinsing until the rinse water runs clear from the container.
6. Puncture or crush the container to prevent reuse.

Paper or plastic sacks and fiber containers

- Empty the contents completely into the application equipment. You may need to cut the container to clean out all of the material in the seams. Never rip the container, but use scissors or a knife (not your personal pocketknife). Wear appropriate PPE such as gloves, eye protection, and in some cases a respirator. Do not let material blow around.
- Rinse the container if you can. Some containers have plastic or foil liners that will allow you to rinse them. Use the rinse water in the spray mixture or collect it for disposal.
- Burning containers can release toxic fumes and cause illness. Burning restrictions vary by county. Check with your county government for burning regulations.

DISPOSAL OPTIONS

Recycling procedures

Only licensed pesticide container recyclers can accept plastic pesticide containers. Do not take them to urban recycling facilities where food containers are accepted.

Only “clean” containers are accepted. Remove caps. Caps are a different class of plastic and can be disposed of in your normal trash. Remove plastic labels and sleeves; paper labels may remain attached.

At collection sites, all containers are inspected, both inside and outside. Stains are acceptable, but **residues** are not.

Landfill procedures

Only “clean” containers are accepted. Plastic/metal containers must be triple rinsed or pressure rinsed. Paper containers must be emptied with their seams as clean as possible. Contact your local landfill for more information.

ADDITIONAL RESOURCES

ASPCA Animal Poison Control Center. 888-426-4435. www.aspca.org. *A $55 credit card fee may apply. A resource for any animal poison-related emergency.*

Chemical Transportation Emergency Center (CHEMTREC). 800-262-8200. www.chemtrec.org. *A resource for obtaining immediate emergency response information for accidental spills.*

National Pesticide Information Center (NPIC). Oregon State University. 800-858-7378. 333 Weniger Hall, Corvallis, OR 97331-6502. http://npic.orst.edu. *Information about pesticides and pesticide-related topics.*

NPIRS State Pesticide Information Retrieval System (NSPIRS). 765-494-6561. 1231 Cumberland Avenue, Ste. A, West Lafayette, IN 47906-1317. http://state.ceris.purdue.edu. *Allows retrieval of state pesticide information.*

Recognition and Management of Pesticide Poisonings, 5th edition. J. Reigart and J. Roberts. EPA #735-R-98-003. 1999. http://npic.orst.edu/rmpp.htm. *Provides information on the health hazards of pesticides and recommendations for the management of pesticide poisonings and injuries.*

American Association of Poison Control Centers. 800-222-1222. www.aapcc.org. *Provides links to local poison centers and poison and drug information.*

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education. See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos. See page 2.*

AQUATIC PLANT BIOLOGY

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Describe the factors that regulate aquatic plant growth

B. Define native versus introduced species

C. Understand how weeds become established

D. Describe common aquatic weed and algal life cycles and growth forms

E. Describe how a herbicide application might affect a water body

F. Understand the difference between monocots and dicots

G. Describe photosynthesis

INTRODUCTION

Aquatic plants are important to the healthy functioning of lake and stream ecosystems. They are essential for many ecological functions, including the production of oxygen for other organisms, the prevention of shoreline erosion, stabilization of the lake bottom, and as food for fish, waterfowl, and other animals. Before taking any action to change the aquatic plant life in a water body, it is necessary to understand the essential ecological role played by a healthy plant community.

In order to properly manage your vegetation community, it is important to understand how aquatic weeds become established and how they are supported by their environment. This understanding will also help you choose the best management option for your particular situation.

GROWTH-REGULATING FACTORS

Sunlight and nutrients are the two factors that have the largest impact on aquatic plant growth and spread. For submersed plants, the depth of light penetration will determine the depth to which such plants will grow. The available plant nutrients determine the amount of vegetation that can be produced. Other important growth factors include temperature, the stability of the **substrate** or bottom, and protection from water and wind disturbance.

Light

Aquatic plants cannot grow in turbid or murky water or water that is too deep because, like all plants, they need sunlight to produce sugars. However, many grow at very low light intensities.

The **photic zone** is the part of a body of water in which light intensity is sufficient to support plant growth. The photic zone, by definition, extends to the depth at which light intensity is equivalent to 1 percent of full sunlight. In muddy ponds, the photic zone may extend only a few inches, while in very clear water bodies, it may extend to a depth of 30 feet or more. The shallower the water body, the more likely it is to have a photic zone that extends to the bottom sediments, where aquatic plants can root and grow.

Water clarity is influenced by the lake's suspended sediments (those stirred up by strong winds or currents), by vegetation, surrounding soils, human impacts, and **water hardness**. Water hardness is a measure of the dissolved elements calcium, magnesium, iron, and strontium. Charged atoms of these elements can bind with suspended particles such as **clay** and **organic matter**, causing them to **precipitate** or settle out of solution.

Precipitation removes particles that would normally reduce water clarity; thus, hard waters are generally clearer than soft waters with low calcium and magnesium concentrations. Clearer waters, in turn, have greater depths of light penetration and may support larger weed populations.

Water clarity can be measured with a device called a **Secchi disk**. This 8–inch diameter black and white disk is attached to a string that has been marked for length, and is lowered into the water until it disappears from view; this length of string is recorded. This measurement is known as the Secchi depth.

Secchi disk[3]

Measuring a lake's clarity regularly can provide valuable information about a lake's biological productivity and can help you decide on the best course of pest management.

Nutrients

Along with sunlight, plants require certain elements for their biological processes. The introduction of large amounts of these nutrients and sediments into water bodies is a primary factor in water quality deterioration. Human inputs, such as wastewater and fertilization, are the most important contributors of excess nutrients to aquatic systems. The elements of chief concern are nitrogen and phosphorus, which can cause eutrophication and are found in most fertilizers as well as in organic wastes.

Phytoplankton (free-floating algae), filamentous algae, and free-floating flowering plants all obtain their nutrients directly from the water. Rooted plants obtain their nutrients from the water column and bottom sediments by root uptake. Therefore, both water and sediment nutrient content is a concern in an aquatic IPM program. Even if water nutrient content is low, dense stands of weeds can grow if they are rooted in nutrient-rich sediments.

Nutrients enter water bodies from the following sources:

- precipitation (rain or snow),
- streams,
- springs,
- **groundwater**, and
- urban and rural runoff (water carrying compounds in solution or soil particles with contaminants bound to them).

A watershed is the area in which these sources are generated and through which they move. In general, the larger the watershed, the greater the amount of nutrients being deposited into a water body; thus, the greater the water body's potential to produce aquatic plants and algae.

Runoff is a major contributor to nutrient loading, the enrichment of surface water nutrients. Excessive nutrient loading leads to eutrophication, the loss of dissolved oxygen from the water, which causes severe reductions in water quality. Often, the most productive areas of water bodies are shallow shoreline areas where nutrient loading from runoff is greatest.

Urban watersheds contribute nutrients in the form of sewage or discharge, storm sewer drainage, and septic field seepage. Agricultural sources include runoff from fertilized fields, feedlots, and pastures. These additional nutrients can be used by algae and aquatic plants to produce excessive vegetative growth.

As algae and plants die, they fall to the lake bottom and decompose. This decomposed material contributes to nutrient loading in the hydrosoil and to the formation of organic materials.

Decomposition is caused by the activity of microbes and bacteria, whose respiration lowers the dissolved oxygen level in a water body. If too much plant material is decomposing, fish kills can occur as a result of a radically reduced dissolved oxygen level.

Many ponds have dissolved oxygen levels less than 10 ppm. Below 3 ppm plants and fish will become stressed. Plant management activities, such as mechanical cutting without harvesting or herbicide treatments, along with seasonal dieback, can dramatically reduce dissolved oxygen in a water body. You should be aware of this possibility when managing aquatic plants. See the chapter entitled Protecting the Environment for a diagram of how pest management can affect an aquatic ecosystem.

Temperature

Temperature is an important factor in determining the life cycles and distribution of aquatic plants. In temperate zones, colder temperatures in the fall, combined with changes in **photoperiod** (day length), cause plants to die back to the soil or bottom sediments. Overwintering aquatic plants include sago pondweed, Eurasian watermilfoil, and elodea.

Most aquatic plants emerge from the sediment when temperatures warm in the spring, sprouting from vegetative structures such as tubers or underground stems called **rhizomes**. They also **germinate** from seeds, root crowns, or overwintering bud structures called **turions**.

Aquatic plants grow best in the warm waters of late spring and early summer, usually reaching maximum size by midsummer. Shallow water warms faster than deep water, and shallow areas usually exhibit the first signs of plant growth, providing aquatic plants with long growing seasons. This is true even in the northern states where the growing season is normally short.

You should be able to observe changes in plant growth as a response to temperature in the lakes and ponds you are managing. This will enable you to predict and identify weed growth stages, which will give you information you can use to decide on a management technique that will be most effective. For example, curly leaf pondweed begins to grow soon after the ice melts. It usually completes its life cycle and collapses around the end of June to early July. The easiest time to control this weed is after its emergence, but prior to turion formation.

Substrate: soil and sediment

A stable substrate, the base on which an organism lives, is required for the attachment of rooted aquatic plants. Sand tends to shift, so does not make a good substrate in flowing waters or along shorelines exposed to wind and wave action. Aquatic plants prefer substrates composed of a good mixture of sand, clay, and organic matter, because those small, charged particles attract and hold nutrients for plants to take up through their roots. Rock and large gravel substrates discourage plant growth because they are nutrient poor.

Slope, topography, and hydrology are also important in substrate suitability. Runoff and erosion of terrestrial sediments may cause buildup along shorelines and at the mouths of inflowing streams; these areas are opportune for plant rooting and seed germination. Shallow areas with gradually sloping bottoms are also prime locations for weed infestations. By contrast, deep water bodies with steep sides provide few sites for plant attachment.

pH

pH is a measure of how **acidic** or **alkaline** (**basic**) a solution is. In other words, it measures the concentration of hydrogen cations (H+) present in a solution. The pH scale ranges from 1 (very acidic, high concentrations of hydrogen ions) to 14 (very alkaline, low concentrations of hydrogen ions). 7 is a neutral pH, in which hydrogen and hydroxide ions are present in equal amounts.

Freshwater lakes and streams range in pH from very acidic (pH 2) to very alkaline (pH 12); however, in the majority of open lakes, pH is between 6 and 9.

The pH scale

WEED ORIGINS

Identifying both native and introduced species in your managed areas will allow you to anticipate changes in aquatic environments due to exotic plant invasion or your management practices. As an aquatic pest manager, strive to promote the continued existence of beneficial plants and minimize the production of weed species.

Native plants are those which have historic origins in the area and were not introduced by human activity. Natural enemies, competition from other plants, and environmental conditions hold many native weed populations in check. Native plants fulfill vital roles in aquatic ecosystems. They stabilize the substrate, filter storm and runoff water as it moves through the area, and provide habitat or shelter for other aquatic organisms.

Introduced plants or **exotic species** came from other parts of the country or world through human activity. Most of our problem weeds are introduced plants. Some escaped plants were intentionally introduced by humans as crops, forage, or ornamentals. They have subsequently spread beyond their intended areas.

WEED ESTABLISHMENT AND PERSISTENCE

Many introduced aquatics are capable of displacing or crowding out native vegetation. Weeds are opportunistic organisms; that is, they take advantage of favorable conditions to propagate and invade an area. Any practice that allows weed seeds to germinate (begin to produce roots and leaves) or that allows plant parts to reproduce will create conditions for weeds to become established in that area.

Weed infestations cause several problems within aquatic ecosystems. Once weeds and algae get a foothold, they spread rapidly, crowding out native vegetation and reducing the economic or recreational value of the waterway. Many, including Eurasian watermilfoil, form dense mats of near-surface vegetation that cover large areas, blocking sunlight to more desirable species below. The mats can make waterways impassable by watercraft and make fishing, boating, and swimming difficult. In addition, they adversely affect the chemistry of the underlying water, degrading the habitat of both fish and their prey.

Weeds spread when seeds or living plant parts (roots, rhizomes, tubers, etc.) are moved into a new territory. Some invading weed species have evolved special seed shapes or structures to aid their movement by wind, water, or animals. Also, many plants have vegetative parts that break off, sprout new shoots, and subsequently root. If these plant fragments are carried into new areas, they may grow and start new infestations. In aquatic areas, it is especially easy for weed populations to become established because of readily available water.

COMMON AQUATIC WEED GROWTH FORMS

Algae (singular, alga) are simple organisms with no roots, though they may have holdfast cells that anchor them to the substrate. They are generally classified as either planktonic, filamentous, or erect.

Planktonic algae are individual algae cells that are suspended in the water or form a film on the surface. These organisms are responsible for low water clarity and may cause allergic or toxic reactions in sensitive people. They can accumulate on the downwind sides of lakes, forming unsightly gelatinous masses on the shoreline.

Many lakes and reservoirs with nuisance planktonic algae also have very fertile hydrosoils. Reducing planktonic algae may result in increased water clarity and therefore increased plant growth. Being aware of this possibility will help you make informed decisions about algal control. Common planktonic algae genera include *Chlamydomonas*, *Euglena*, and *Closterium*.

Filamentous algae can be split into two groups: attached or free-floating. Attached algae have some kind of holdfast cell that anchors them to rocks or other substrates. They are usually found on docks, seawalls, boats, and other hard surfaces. They vary in texture from slimy to coarse and hair-like. Free-floating filaments often form mats on sediments, continually increasing in size and layers. These layers can form unsightly floating rafts on the water surface that trap debris. These rafts are commonly referred to as "**pond scum**."

Filamentous algae can become a problem on soils where large rooted plants have been removed without caution, or where nutrient concentrations are high. Reducing nutrient loading can help control nuisance filamentous algae, if they are not growing on nutrient-rich sediment. Common genera of filamentous algae include *Spirogyra*, *Oscillatoria*, *Oedogonium*, and *Anabaena*.

Erect algae resemble vascular plants and grow from the sediment. They do not have roots, but have holdfast structures similar to those in filamentous algae. These organisms are considered valuable in maintaining water quality, because they cover the sediment and absorb nutrients that are released. This aids in preventing the establishment of other nuisance algae or plant species. Erect algae genera include *Chara* and *Nitella*.

Algae growing in a lake.[4]

Control of the various algal groups can be achieved through a few basic techniques, though methods and application rates will vary for each situation. One method is to broadcast an algaecide over the entire water and algae surface. Large mats of algae can be broken up with a boat propeller or high-pressure stream of water.

ALGAL LIFE CYCLES

Algae do not have the complex sexual structures of their land-based relatives; therefore, their life cycles are based more around the dispersal of reproductive cells than around any particular time of year. Algae propagate through both **gametes** (sex cells) and spores, as well as through fragmentation. Many algal spores are **zoospores**: they have **flagella** and can swim through the water. Because they are either unicellular or loosely attached congregations of cells, most algal cells can reproduce at any time. This is how algal blooms appear so suddenly; in the presence of favorable water conditions such as high nutrient content, algal cells will begin to replicate as fast as possible.

In most algae, the resting state is the **zygote**, a cell analogous to the embryo that develops in vascular plant seeds. The zygote is protected by strong compounds that surround it and prevent it from drying out in unfavorable conditions; when favorable conditions return, it can undergo cell division and propagate new cells into the water body. This makes algae particularly difficult to eradicate completely.

FLOWERING PLANTS

Aquatic flowering plants have several dominant growth forms.

Submersed

Submersed plants grow completely below the water surface and depend on the nutrients in the water for physiological functions. Common submersed plants are the watermilfoils, naiads, pondweeds, coontail, and elodea. They reproduce primarily by vegetative **fragmentation**, vegetative reproductive structures, or seeds.

Elodea canadensis (Canadian waterweed)[5]

Emersed

Emersed or **emergent** plants are rooted in the sediments. They extend above the water surface and are self-supporting. Common emergent plants are cattails and purple loosestrife (a noxious weed). These plants principally reproduce by vegetative means, from rhizomes or stolons in the hydrosoil; however, they may colonize new areas by seed dispersal.

Purple loosestrife[6]

Free-floating

Free-floating plants are not attached to the substrate and float on the water surface or just below it. They have roots that extend into the water for nutrient uptake. Examples include duckweed and watermeal. These plants reproduce vegetatively, by fragmentation, and irregularly by seed.

Common duckweed[7]

Rooted

Rooted floating plants are attached to the sediment and have leaves that float on the water surface. Some are supported by the water alone, while others have a more rigid structure. Examples include water lilies and American lotus. These plants reproduce most often via vegetative means.

American lotus[8]

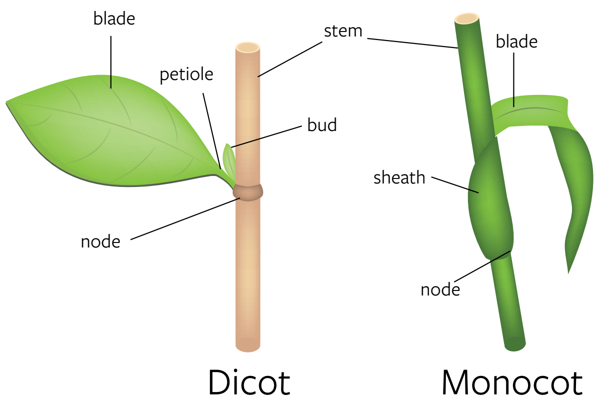
Monocots and dicots

Flowering plants can also be divided into monocots and dicots.

Monocots

When monocots germinate, they have a single primary leaf or cotyledon; the cotyledon does not emerge above the soil surface and the first leaves you see are actually secondary or true leaves. All monocots have narrow leaves with parallel veins (thus the term "narrow-leaved" plants) and usually have a fibrous root system. They most commonly reproduce by seed, stolons or rhizomes. The growing point in monocots is frequently at or below the soil surface, particularly in young plants. Monocots include the grasses and cattails, as well as pondweeds, naiads, and watermeal.

Dicots
When dicots emerge from the soil, they have two primary leaves or cotyledons. The cotyledons often do not look like the later true leaves. Dicots usually have broad leaves (thus the term "broad-leaved" plants) with veins that form a net-like pattern. All species can reproduce by seed, but some have vegetative buds in the crown and still others reproduce by spreading rootstocks. Dicots include broadleaf weeds and forbs, shrubs, and trees. They also include the watermilfoils, coontail, and water lilies.



COMMON AQUATIC WEED LIFE CYCLES

Plants can be classified according to their cycles as **annuals**, **biennials**, or **perennials**. These are not strict botanical divisions, but groupings that are important in determining how to control the plants.

Annuals
Annual weeds mature in one season and are propagated exclusively by seeds. When mature, the seeds sink to the soil or hydrosoil and remain dormant until conditions for germination are favorable. These plants die back to the substrate in the winter. Among the aquatic annuals are coontail and some of the naiads.

Summer annual weeds grow from seeds that sprout in the spring, mature, and reproduce before dying in the winter.

Winter annual weeds germinate in the fall or winter and grow until spring when they flower, produce seed, and die.

Annuals are easily controlled by weeding, **dredging**, or herbicides, especially if control methods are undertaken before the plants have set seed.

Biennials
Biennial weeds require two years to develop and complete their life cycles. In the first year, these plants often produce basal leaves called a **rosette** (basal leaves), and a taproot, in the second year, the plant flowers, produces seed and generally dies.

Perennials
Most aquatic weeds are perennials. Perennial weeds are plants that live indefinitely; they may lose their foliage during the winter and die back to the substrate, but they recover in the spring. They flower and set seed without dying. Common examples are the pondweeds, water lilies, and cattails.

Most aquatic perennials are **herbaceous** (soft-bodied). Perennials reproduce both vegetatively and by seed, and can store food in their roots or rhizomes.

WEED GROWTH STAGES

Like all flowering plants, weeds develop through four growth stages: seedling, vegetative, flowering, and maturity.

Annual plants
Vegetative
Plants in the vegetative growth stage use most of their energy resources to produce stems, leaves, and roots.

Flowering

During this time, most weed energy resources go into seed production.

Maturity

Maturity and seed set complete the life cycle of annuals.

Perennial herbaceous plants

Perennial weeds vary in growth habits. They differ in development rate, root reserve depletion, dieback of shoots after flowering, and regrowth after flowering.

ADDITIONAL RESOURCES

Freshwater Algae of North America: Ecology and Classification. J. Wehr. Academic Press: 2002. *General information about algal ecology, physiology, and taxonomy.*

Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation. A. Pieterse and K. Murphy. Oxford University Press: 1990. *Ecology, characteristics, and management of aquatic weeds.*

Aquatic and Riparian Weeds of the West. J. DiTomaso and E. Healy. University of California Agriculture and Natural Resources: 2003. *Provides information on weed identification, habitats, distribution, and control methods, with color photographs.*

USGS Nonindigenous Aquatic Species Database. https://nas.er.usgs.gov/default.aspx. *Accurate and spatially referenced biogeographic accounts of invasive aquatic plants, vertebrates, fish, mollusks, and insects; plus scientific reports, online queries, regional contact lists, and general information.*

Center for Aquatic and Invasive Plants, University of Florida. 7922 NW 71 Street, Gainesville, FL 32653 or PO Box 110410.Phone: 352-392-1799. https://plants.ifas.ufl.edu/. *Plant information and images, online databases, books, and field guides related to aquatic and invasive species.*

USDA PLANTS Database. http://plants.usda.gov. *Provides standardized information about nearly every species of plant in the U.S., including names, plant symbols, checklists, distributional data, species abstracts, characteristics, images, crop information, automated tools, onward Web links, and references.*

Aquatic Ecosystem Restoration Foundation. www.aquatics. org. *Supports research and development on strategies for environmentally sound management, conservation, and restoration of aquatic systems. Available on the site is Biology and Control of Aquatic Plants: A Best Management Practices Handbook.*

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education.* *See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos.* *See page 2.*

AQUATIC HERBICIDE TECHNOLOGY

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Understand and describe water use restrictions
B. Understand contact and systemic herbicides
C. Define selectivity
D. Describe factors that affect herbicide selectivity
E. Describe various herbicide modes of action
F. Describe factors that affect herbicide performance
G. Understand resistance and how to prevent it
H. Describe herbicide formulations

INTRODUCTION

A single herbicide application rarely provides a permanent solution to a weed problem. It is likely that, combined with biological, physical, and cultural control, a regular management program will be the most effective means of weed control. Even when a weed species is known to be susceptible to a certain herbicide, it is not always appropriate to use it; other control methods may be preferable based on the particular characteristics of the specific water body.

There are major differences between the characteristics of herbicides in water and terrestrially. They do not control the same weeds, and environmental conditions affect them differently. Some are more toxic to aquatic than terrestrial animals; some are less persistent in water than on land. It is the responsibility of the applicator to choose the most appropriate herbicide for the given aquatic conditions.

You should consider the following when choosing a herbicide:

- **water use restrictions** associated with the herbicide's use,
- whether the herbicide is a contact or systemic chemical,
- the herbicide's level of selectivity, and
- the herbicide's **mode of action.**

WATER USE RESTRICTIONS

The use of aquatic herbicides in a water body may require restricting water use until the herbicide has degraded, become inactivated, or dissipated. One of the most critical steps in choosing an aquatic herbicide, therefore, is determining the present and potential uses of the water.

Post-application water restrictions are imposed for several reasons. Foremost is the protection of the public from exposure to potentially harmful chemicals. In addition, water use restrictions prevent people from disturbing the lake water and sediments, which could reduce the **efficacy** of the treatment. Chemical compounds must be absorbed by plants in large enough quantities to cause death. Water movement or recreational usage soon after application may reduce herbicide efficacy.

Each pesticide has its own water use restrictions based on several factors, including residue **tolerances**, the pesticide's environmental fate, and other data required for pesticide registration. Swimming, fishing, irrigation, livestock watering, and domestic use restrictions may be present on the pesticide label, and should always be followed. The period of restriction can range from a few days to months, depending on the rate of application and the persistence of the pesticide in the aquatic system.

Herbicides may also be restricted based on the type of water body to be treated. A herbicide or a formulation may be restricted to a certain type of site, such as an irrigation canal rather than a drainage ditch, or non-flowing rather than flowing water.

You should consult your local Department of Agriculture about restrictions that may not be noted on the pesticide label. Restrictions are usually imposed for streams, public or multiple-use lakes, and reservoirs.

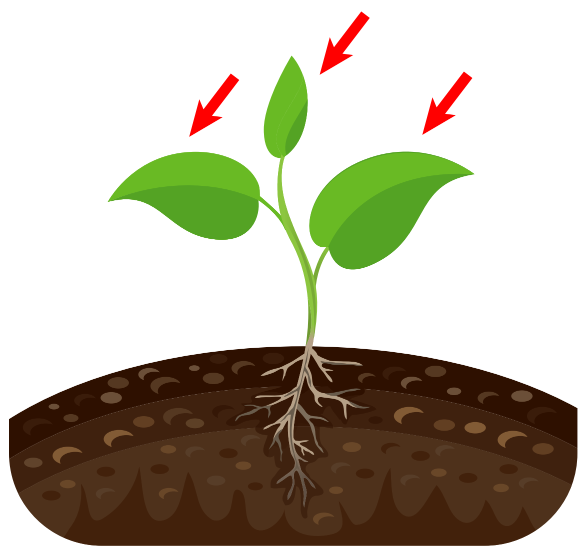
UPTAKE AND MOVEMENT: CONTACT AND SYSTEMIC HERBICIDES

To be effective, herbicides must be absorbed by the plant. You can treat the foliage of emerged or floating plants, or you can treat the entire water column. Herbicide movement and activity within a plant differs among plant species and herbicides. This is why some herbicides work better on certain species, while having little effect on others. Annual or biennial broadleaf weeds can be controlled by foliar applications, but the herbicide must move to the roots to control perennials.

Contact herbicides

Contact herbicides are applied to plant foliage and only affect plant parts they directly contact. They do not **translocate** (move) effectively through the plant. Therefore, the herbicide must be distributed evenly over the entire weed. In general, these herbicides disrupt cell membranes. Activity can be very quick, with visible damage occurring within a few hours for some herbicides.

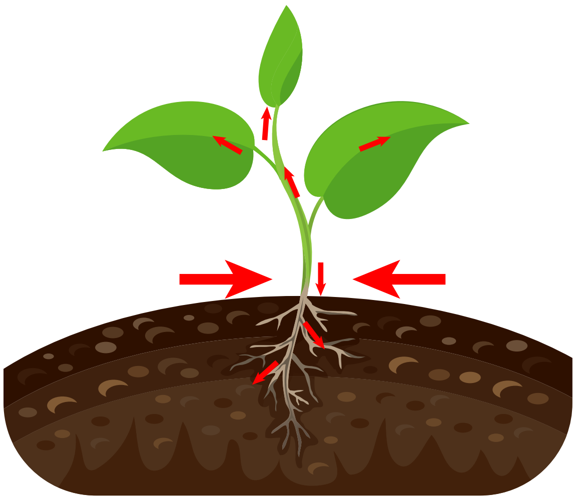
Contact herbicides effectively control some annual weeds, but only affect the shoots of perennials, leaving the underground system to resprout. Repeated applications to perennial weeds may deplete the food reserves in underground plant parts, eventually causing death. Diquat and endothall are examples of contact herbicides.



Contact herbicide

Systemic herbicides

Systemic herbicides are absorbed through the foliage, stem, shoots, or roots and move throughout plants. Most translocated herbicides are foliar-active, meaning that they are absorbed by leaves and move with sugars to actively growing plant parts such as shoot tips and roots. As a result, injury is often first seen in developing tissues.



Systemic herbicide

Because they can move within the plant, these chemicals effectively control perennial weeds and do not have to be applied uniformly over the whole plant to produce good results. However, because they must move throughout the plant, and have slower acting modes of action, these herbicides act more slowly compared to contact herbicides. A majority of aquatic are systemic and include examples like 2,4-D and glyphosate.

SELECTIVE AND NONSELECTIVE ACTIVITY

Selective herbicides

The selectivity of a herbicide refers to whether a plant is **susceptible** to or **tolerant** of the herbicide. Susceptible plants are affected by the herbicide, whereas tolerant plants are not. One advantage of chemical control is that some herbicides kill only selected weeds. Herbicides that control weeds while doing little or no damage to the desirable vegetation are **selective herbicides**.

Nonselective herbicides

Nonselective or **broad-spectrum** herbicides kill or control almost all plants—desirable vegetation as well as weeds. Some nonselective herbicides persist for long periods of time, providing **residual** control.

Selectivity

Selectivity depends on many interrelated factors. It is influenced by the herbicide's mode-of-action and formulation, the application rate, method, and timing, as well as environmental conditions.

Even closely related plants may respond differently to applications of the same herbicide. Selectivity may be lost through applicator mistakes or if the herbicide is applied when desirable plants have been under stress or are at the wrong growth stage.

This does not mean that selectivity is difficult to achieve. It can be as simple as careful herbicide placement. For example, if small populations of purple loosestrife are growing among cattails, applicator can control the loosestrife with minimum impact on the cattail community using spot applications.

The applicator must understand the reasons for a herbicide's selectivity to avoid injuring desirable vegetation. Herbicide selectivity is determined by both plant and chemical factors.

Plant factors

The uniqueness of each plant species is the result of its particular combination of structures and **physiology**. The extent to which a herbicide affects any plant species depends on the plant's structure and physiology.

Structure

To be effective, the herbicide must enter the plant. The plant's size, leaf shape, hairiness, and the thickness of its **cuticle** are all factors that greatly affect the retention and absorption of foliar-applied herbicides. Plants with upright leaves, extremely hairy leaves, or thick cuticles, which are difficult to wet, are less likely to retain sprays. Submerged plants usually have little to no cuticle. These differences may help make a plant either susceptible to or tolerant of herbicides. Plant size also makes a difference. Older, larger plants often require higher dosages or rates than seedlings. Leaf shape may affect the amount of herbicide you should use. Herbicide sprays tend to bounce or run off plants with narrow vertical leaves, while broadleaved plants tend to hold the spray.

Plant physiology

Selectivity primarily depends on how the plant responds after the herbicide enters its tissues. Herbicides kill susceptible weeds by interfering with vital plant processes. Some plants can **metabolize** the herbicide fast enough to prevent injury or death. In certain cases, stress such as cold weather can slow a plant's ability to metabolize herbicides and some injury may occur.

Chemical and application factors

Several simple physical factors affect herbicide selectivity:

1. *what*—formulation,
2. *how much*—application rate (amount applied),
3. *where*—application placement,
4. *when*—application timing, and
5. *how long*—herbicide persistence.

Formulation

Selectivity may depend on how the herbicide is formulated. Many herbicides are available in both granular and liquid formulations.

Application rate

Some herbicides are selective at lower application rates; however, when the same herbicide is applied at a higher rate, the herbicide becomes nonselective. For example, woody perennial plants may tolerate low doses of herbicides that effectively control annuals and biennials.

Application timing

Many herbicides are effective only if applied at the proper time. The time of application is usually given on the label. You must understand the following label terms regarding application timing.

In general, one growth stage is more vulnerable to different types of weed control strategies than the others. If chemicals are not applied during this optimum growth stage, changing the method or increasing the herbicide rate (but never over the labeled rate) may be necessary.

Pre-emergence is a treatment made prior to the emergence of the weed and commonly applied to the soil. Therefore, in aquatic environments, these applications are usually made during winter drawdown. If weeds are present, you may need to mix the pre-emergent herbicide with a post-emergence foliar herbicide. While pre-emergence treatments can be effective in seasonally dry areas, they are not generally used for submerged species.

Post-emergence is any treatment made after emergence of a weed. Apply the herbicide after the weeds are up. This is usually a foliar application for emergent of floating species, or a water column treatment for submerged species. In general, plants are most susceptible to post-emergence herbicides at two specific growth stages: as seedlings when rapid growth takes place, and, for perennials, once they are past the seedling stage, when a period of rapid growth has ended and food reserves are temporarily depleted or exhausted.

The seedling growth stage is susceptible in all weeds, whether they are annuals, biennials, or perennials. Seedling weeds are small, actively growing, and more easily controlled than any other growth stage. This is true for both mechanical and chemical control. Most aquatic herbicides are applied when weeds are actively growing. At this time, herbicides are easily able to penetrate and translocate within the plant. A second reason for early treatment is that cool water contains more oxygen than warm water; this provides a margin of safety for fish.

Algaecides can be particularly sensitive to application timing. Treatment with copper compounds must be done on bright, sunny days when the algae are actively photosynthesizing and releasing oxygen. You can use less herbicide during early developmental stages, when algae concentrations are low and the organisms are dispersed throughout the water.

Later in the season, large algal mats may form that require more intensive herbicide use or other management methods. Rapid algae kills can result in oxygen depletion, so early season treatment is desirable, since waters are well oxygenated and populations are low at this time.

Concentration and exposure time

A pesticide must be in contact with the target pest at sufficient concentrations for a sufficient period of time in order for the chemical to be effective. This dose/response phenomenon is herbicide- and plant-specific and has been defined as a **concentration and exposure time** (**CET**) **relationship**. This is one of the most important concepts in aquatic plant management. Poor pesticide performance, especially in submersed applications, can often be traced to insufficient concentration or exposure time. We can think about this using a formula:

$$\text{Efficacy} = \text{Concentration} \times \text{Exposure Time}$$

If an efficacy of total control is equal to 1, we can solve this equation with a variety of different concentrations and exposure periods. If the concentration is 0.5, how long must the length of exposure be?

$$1 = 0.5 \times \text{Exposure Time}$$
$$\text{Exposure Time} = 1 \div 0.5 = 2$$

This means that if we apply a pesticide at half strength, we must double the length of exposure to achieve total control. Conversely, if we cannot keep a pesticide in contact with the target pest for long enough, we must increase the concentration accordingly.

The two key factors that determine concentration and exposure time are:

1. herbicide dispersion, and
2. herbicide degradation.

Herbicide dispersion or dilution is the mixing of the herbicide with water. We do need some dispersion so that the herbicide is mixed thoroughly in the water column; however, if the herbicide becomes too dispersed, it will not be effective. This is especially important in partial lake or spot treatments. Factors that influence dispersion include whether the treated water is protected (i.e., in a cove or inlet) and weather conditions like rain or wind that can increase dispersion. Water flow and dilution may result in a herbicide CET that is insufficient for herbicides to be effective.

Herbicide degradation proceeds via several pathways including pH, microbial activity, **adsorption** to clays and organic matter, and **chemical degradation**. These factors are discussed in the chapter of this guide titled *Protecting the Environment,* page 56.

Persistence

Another important consideration when choosing an aquatic herbicide is the chemical's persistence in the environment. Persistence refers to the length of time that a pesticide applied to the water column prevents the establishment or growth of plants. Sometimes these pesticides are desirable because they provide long-term pest control and may reduce the need for repeated applications. Residual activity is important because of potential injury to future plant communities. Persistence is controlled by the same factors that influence dispersion and degradation.

MODES OF HERBICIDE ACTION

Understanding how herbicides control weeds often is useful in selecting the proper herbicide for a particular weed. It also may be useful in recognizing herbicide injury to plants. There are seven major modes of action; however, because there are few herbicides approved for aquatic use, you may not encounter each type in your work.

Growth regulators disrupt the normal hormone balance and protein synthesis in plants, causing growth abnormalities. 2,4-D and triclopyr are examples.

These herbicides translocate to the growing points of the plants, and injury symptoms appear in new plant tissue. An early symptom is often **epinasty**: abnormal bending or twisting of shoot tips, stems, leaves, and **petioles**.

Amino acid synthesis inhibitors prevent the production of some amino acids that form proteins fundamental to normal plant development. Symptoms of activity may include **stunting**, **chlorosis** (yellowing), or purpling of leaves. The imidazolinones are examples of amino acid synthesis inhibitors. Imazamox and glyphosate are specific examples.

Cell membrane disruptors destroy plant tissue by disrupting plant cell membranes. These are contact herbicides having little or no mobility in the plant and must be applied post-emergence. They are excellent for rapid foliage burn-down and control of annual weeds. Symptoms include rapid wilting and **necrosis** of plant tissue. Copper compounds are examples of cell membrane disruptors, along with bipyridyliums such as diquat.

Pigment inhibitors target a plant specific enzyme that protects **chlorophyll**, the green pigment responsible for photosynthesis in plants. Because they are unable to make pigments, the affected leaves turn white or translucent; weeds will appear white prior to dying. Because emerged plants constantly replace pigments, the plant will turn white following treatment. Fluridone is one example.

Below are two tables of commonly used aquatic herbicides, both contact and systemic, detailing their mode of action, persistence, and selectivity.

Contact Herbicides

Active Ingredient	Mode of Action	Persistence	Selectivity
Copper chelates	Cell membrane disruptor	Low	Algae and green plants
Copper sulfate	Cell membrane disruptor	Low	Algae and green plants
Diquat	Cell membrane disruptor	Low	Non-selective
Endothall	Unknown	Low	Pondweeds, coontail, algae
Flumioxazin	Amino acid syntheses inhibitor	Low	Broadleaf

Systemic Herbicides

Active Ingredient	Mode of Action	Persistence	Selectivity
2,4-D	Growth regulator	Low	Broadleaf weeds
Fluridone	Pigment inhibitor	High	Rate-dependent
Glyphosate	Amino acid synthesis inhibitor	Low	Non-selective
Imazamox	Amino acid synthesis inhibitors	Low	Broadleaf weeds
Triclopyr	Growth regulator	Low	Broadleaf weeds

FACTORS AFFECTING PESTICIDE APPLICATION AND PERFORMANCE

Several different variables affect how and when you apply a given herbicide. These variables also affect the efficacy of a given application, and include:

- human error,
- climatic factors,
- photodegradation,
- water movement,
- water chemistry,
- hytotoxicity,
- pesticide compatibility,
- microbial activity, and
- weed growth stage.

Human error

Application mistakes are frequently responsible for pesticide failures. Pesticides are most effective when applied at labeled rates. Placement of a soil pesticide is also important. **Calibration** errors, along with simple mathematical mistakes, can contribute greatly to a pesticide's failure. Follow the procedures outlined in this guide, along with the label directions.

Climatic factors

Climatic factors such as temperature, precipitation, wind, and humidity affect weed growth and control, as well as the safety of desirable vegetation.

Temperature

Both water temperature and ambient air temperature can affect the suitability and efficacy of a given herbicide application.

Low water temperatures are often desirable when controlling aquatic weeds, because cool water contains more oxygen and therefore provides a margin of safety for fish and other organisms after the plants have been killed. On the other hand, most herbicides should not be applied when the water is too cold (below 60°F). While plants do grow at these temperatures, they may not be metabolizing (processing light and sugar) fast enough to absorb sufficient quantities of herbicide. While low water temperatures may affect herbicide efficacy, high water temperatures may also have an impact. Herbicides, such as endothall, that are broken down through microbial degradation may be rapidly degraded in very warm waters, impacting CET. If herbicide is lost too quickly, efficacy can be reduced.

Remember that even though air temperatures may be above 60°F, water temperatures tend to lag behind warming air temperatures in the spring and will remain low for some time. This means that you may want to treat emergent annual weeds with a contact herbicide, which will be active in the warm air temperatures, before you treat submerged weeds with a translocated herbicide, which may not be as effective at low water temperature.

Low air temperature also affects herbicide efficacy indirectly because it, too, affects plant growth. At less than optimum temperatures, plant growth slows, which may decrease herbicide absorption and activity.

Wind

Wind can affect herbicide applications in several ways. Windy conditions decrease the efficiency of foliar applications to emerged plants because of poor coverage. Wind can also affect the leaf's ability to absorb the chemical. Applications should not be made when wind is strong enough to cause drift.

Wind may also affect the efficacy of pesticide applications for submersed plant management. A pesticide must be in contact with the target pest at sufficient concentrations for a sufficient period of time in order to achieve control; however, wind can cause water movement that may carry the chemical away from the target area.

Photodegradation

Exposure to sunlight increases the rate of **photodegradation** of some pesticides. Sunlight-induced transformation can be an important factor in the failure of aquatic pesticides. These changes generally alter the chemical properties of a pesticide, making it less toxic, less effective, and more susceptible to further breakdown by chemical or microbial processes. Photodegradation is the main reason that these herbicides are less persistent in water.

Water movement

Most pesticides used for submerged weed management must be absorbed from the water into target plants. A sufficient amount of pesticide must be available in the water long enough for it to be effective. It is difficult to manage submersed aquatic weeds or invertebrates in rapidly flowing water where the pesticide is carried away from the plants with the water flow. The following techniques may need to be used even in slow-moving water:

- using trailing hoses to aid the pesticide in sinking below the surface and contacting plants,
- using special pesticide formulations for flowing water,
- using rapidly absorbed pesticides, or
- using repeated sequential applications or injection equipment to increase contact time.

Water chemistry

Usually, the applicator has little control over a lake's water chemistry; however, knowing these parameters can help you decide which pesticides are most appropriate for the specific site and situation.

pH

Soil and water pH can alter pesticide effectiveness. Very low or very high pH may render a pesticide completely ineffective. Warnings about this interaction are sometimes included on the label.

Turbidity

Turbidity is a measure of the amount of particles suspended in the water. These particles affect the water's clarity and ability to transmit light. They can be either biological, such as plankton and other microorganisms, or inorganic, such as clay and minerals. Organic or clay particles are of most concern for the pesticide applicator, because they can bind to pesticide molecules and render them ineffective.

You should always be careful to not increase turbidity by disturbing bottom sediments by walking on the bottom or getting too close to the bottom with boat propellers, or any other machine that disturbs the water. In addition, be cautious when using turbid water as a **diluent**; it too can bind pesticides in the tank, and may clog pumps and hoses.

Hardness

Water hardness is a measure of the concentrations of dissolved ions, mainly calcium and magnesium. Knowledge of water hardness is important to the aquatic pest manager because certain pesticides can react with the minerals in hard water. This may cause the chemicals to become inactive or to precipitate. This can happen in the lake water or in the tank. Using softened water may aid in preventing precipitation in certain applications.

Copper compounds tend to be particularly sensitive to water hardness. Inorganic copper algaecides are much more effective in soft water, which is defined as a solution containing less than 50 ppm as $CaCO_3$, **calcium carbonate**. Application rates must be adjusted accordingly to avoid impacting nontarget species, particularly fish. If you are using copper in hard water, **chelated** forms are the most effective, because they stay in solution longer, are more readily absorbed by plants, and are less toxic to fish.

In general, you should take the following precautions to mitigate the effects of water chemistry on the efficacy of your application:

- Use the cleanest water possible.
- When tank mixing compounds that may be inactivated by hard water, use the softest water available.

- Minimize the time that pesticides remain mixed in the tanks.
- Read the label for special precautions or instructions.

Phytotoxicity

A pesticide that injures a plant to which it is applied is said to be phytotoxic. Phytotoxicity may occur due to drift onto nontarget plants, excessive rates, mixing of pesticides that are not phytotoxic when used alone, and using pesticides in a more concentrated form than is desirable.

To avoid undesirable phytotoxicity, apply pesticides within recommended rates. Do not mix pesticides unless the label indicates it is safe to do so. Apply and mix pesticides according to label recommendations.

Pesticide compatibility

It is often desirable to mix two or more pesticides during application. When these mixtures can be made without reducing safety or effectiveness, the mixture is said to be **compatible**. However, often such mixtures cannot be made since the chemicals are **incompatible**. Incompatible mixtures can increase the toxicity or hazard of the mixture to the applicator or the environment. Incompatible mixtures may also greatly reduce the effectiveness of the spray mixture or may cause plant injury.

Incompatibility can involve undesirable physical changes in the mixture. For example, a mixture may cause material to precipitate as a solid and deposit on the bottom of the spray tank. **Physical incompatibility** may also cause the components to form separate layers following agitation. Large aggregates may form, or curdling of the mixture may occur. These types of physical incompatibilities may result in an unsprayable mixture or cause fluctuations in the amount of pesticide being applied.

Chemical changes may also occur when pesticides are mixed. This is particularly common where acidic or alkaline materials are used. Reactions in the tank may form compounds that increase environmental hazards, reduce the amounts of active ingredients, or cause plant injury.

Increasingly, tank mixes of two or more compounds are specified on pesticide labels. Compatibility problems should be minimal with these previously tested and registered combinations. Where such combinations are not specifically labeled, pesticide applicators may make tank mixtures unless the label instructions prohibit it. However, where specific tank mixes have not been extensively tested, use caution to avoid problems.

To prevent incompatibility of different pesticides in a spray mix, add chemicals in the following order:

1. wettable powders,
2. flowables,
3. soluble powders,
4. liquids, and
5. surfactants.

If mixing two chemicals in a tank mix that was not specifically recommended on the label, conduct a jar test for compatibility first.

Microbial activity

Microbial degradation is decomposition through microbial metabolism. Different microbes can degrade different herbicides, and consequently, the rate of microbial degradation depends on the microbial community that is present. Soil and water conditions that maximize microbial degradation include warmth, moisture, and high organic content.

Weed growth stages

In general, one growth stage is more vulnerable to different types of weed control strategies than the others. If chemicals are not applied during this optimum growth stage, changing the method or increasing the herbicide rate (but never over the labeled rate) may be necessary.

Growth stage can affect susceptibility in several ways. Young, actively growing annual plants that have not developed a cuticle or leaf hairs are more susceptible to foliar-applied herbicides than mature plants. The physiology of perennial plants changes during the growing season. During early stages of growth, food reserves and other plants compounds are transported upward from the roots very rapidly; at this time, soil-active compounds are readily absorbed and transported to the growing points. On the other hand, foliar-active herbicides are least effective during this time, and plants may tolerate the treatment.

During late and post-flowering periods, perennial plants are completing their yearly growth cycle. They are transporting material downward to the roots for storage, and are most susceptible to foliar-active herbicides that move downward with the plant materials.

The seedling growth stage is susceptible in all weeds, whether they are annuals, biennials, or perennials. This is true for both mechanical and chemical control.

Annual plants

Seedling annuals are small, actively growing, and more easily controlled than at any other growth stage. Usually, this stage requires higher rates of herbicide. It is very difficult to kill older annual plants with chemicals; however, foliar herbicide applications at this stage may prevent seed production. Once seed production has occurred, chemical control is neither effective nor practical.

Biennial plants

Biennials are best controlled in the first year of growth, before flowering and seed production takes place. Control of the rosette stage is second best. Control decreases as plants mature.

Perennial herbaceous plants

Like annuals and biennials, perennials are easiest to control during the seedling stage. However, successful control of established perennial plants requires translocation of herbicide into the perennial plant's underground system (roots, rhizomes, tubers) to kill the entire plant. Two key facts will help you understand perennial weed control. Plants store sugars in their roots during winter. In the spring, they use the sugars to growth shoots, depleting the root reserves. In the summer and fall after flowering, the plants restock the roots with sugars for the next year's growth.

PESTICIDE RESISTANCE

Some pest species have become resistant to once effective and widely used pesticides. **Pesticide resistance** is a measurement of a pest's ability to survive the toxic effects of a specific pesticide application. As the number of resistant individuals increases in a pest population, the original application rate or spray frequency no longer provides adequate control.

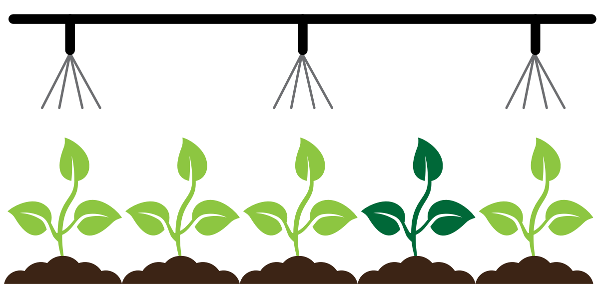
You must know the difference between pests that are naturally tolerant and pests that have become resistant to pesticides over time. As with any pesticide treatment, some pests are tolerant and will survive, while susceptible pests will die. Tolerant pests occur naturally, while resistant pests appear after continual use of the same pesticide, or of pesticides with the same mode of action, over many years. Using pesticides with different modes of action is necessary to prevent resistance.

The development of resistance

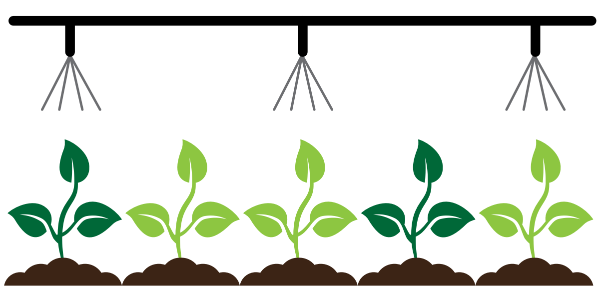
Resistance in pests results from natural genetic variation in individuals. Some pests in a population may be resistant to a given pesticide because of different genes. Resistant organisms may be few, perhaps only one for one thousand individuals of that species; however, one resistant pest may survive and produce resistant offspring. If the same pesticide is used the next year, more resistant individuals may survive in the site and produce more resistant offspring. The number of resistant organisms will increase each year until poor control is noticed. Generally, resistance is genetically dominant; that is, if a resistant pest and a sensitive pest cross, the offspring will be resistant. There are many mechanisms of resistance. Resistant individuals may:

1. Change the uptake or translocation of the pesticide within the pest so that the pesticide no longer reaches its target site.
2. Change the site of action or target enzyme to that the pesticide no longer functions effectively.
3. Metabolize or break down the pesticide into less toxic compounds.
4. Sequester or isolate the pesticide in its cells so that the pesticide cannot reach the active site.
5. Avoid the pesticide through their own action—this is called behavioral resistance.

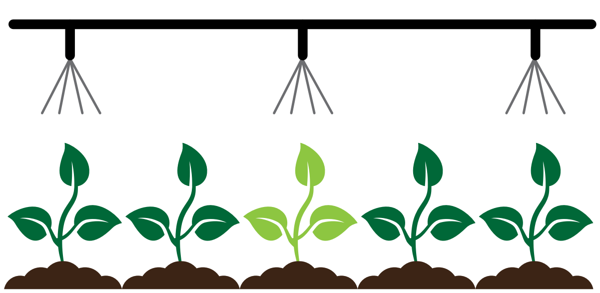
Pests that are resistant to one pesticide may show resistance to other pesticides with the same mode of action. This is called **cross-resistance**. Cross-resistance occurs because closely related pesticides kill insects or weeds in the same way. If a weed can resist the toxic action of one chemical, it may survive applications of other chemicals that kill in the same way. **Multiple resistance** occurs when the pest is resistant to two or more pesticides from different classes of compounds with different modes of action.



1. Pesticide is applied and a resistant variety survives.



2. Resistant variety produces offspring.



3. Resistant variety becomes prevalent in the ecosystem.

Resistance management

Since fewer new pesticides are being developed, we cannot afford to lose the use of current pesticides to resistant organisms. We must use strategies to prevent resistance development.

Avoid practices that favor pesticide-resistant weeds. Use the following resistance management strategies:

- Use IPM. Implementing other methods of pest control along with pesticides will delay or prevent resistance. See the chapter titled Integrated Pest Management for more information.
- Rotate among pesticides with different modes of action.
- Resist the temptation to use higher rates when pest control starts to decline. If the uncontrolled individuals in the population are genetically resistant, increasing the pesticide dosage will not kill them. It will simply eliminate the susceptible types,

Summary of Formulation Types

Name	Description	Advantages	Disadvantages
Solids			
Dry Flowable (DF)/Water Dispersible Granule (WDG)	• Formulated into small pellets or granules • Forms a suspension in water	• Require less agitation than WP • Easier to measure and mix than WP • Less inhalation hazard than WP	• Spray mix requires constant agitation • Abrasive
Granular (G)	• Mix or dry, large free-flowing particles • Usually with a low ai concentration	• Ready to use • No mixing • Minimal drift • Ideal for spot treatments • Best used for submersed species	• Some dust
Soluble Powder (SP)	• Dry material that goes into true solution when mixed with water	• Agitation not needed after mixing	• Dust can be inhaled
Liquids			
Concentrated Emulsion (EW)	• Consist of thick water-based emulsion and an ai paste • Diluted in a spray tank for application	• Minimize level of solvent needed to dissolve pesticide and emulsify the solution in water	• Hazardous if ingested
Emulsifiable Concentrate (EC or E)	• Clear solution with emulsifiers to be diluted in water • Final spray solution has a milk look	• High concentration of ai so less product to store, purchase, or transport • Easily mixed • Non-abrasive	• Amount of ai increases mixing hazard • May cause leaf burn • Flammable • Easily absorbed through skin
Flowable (F)	• Finely ground particles suspended in a liquid carrier • Forms suspension in spray mix	• No dust • Premix not needed	• Needs agitation before mixing, as ai may settle out • Abrasive
Gel	• Semi-liquid, emulsifiable concentrate	• Used with WSP	• Cannot measure amounts smaller than packaged size
Micro-encapsulated Suspension	• Suspension with ai impregnated in very small, slow-release plastic beads	• Easy to mix and apply • Reduces hazard to operator	• Agitation needed • Can be very hazardous to bees
Suspension Concentrate (SC)	• Finely ground particles in a liquid base • Forms suspension when diluted with water	• Easily mixed	• Easily absorbed through skin
True Liquid Solution (L)	• ai is in solution, usually water • When mixed with water, remains clear	• Easily mixed	• Possibly corrosive
Packaging			
Water Soluble Packets (WSP)	• Preweighed amount of WP, SP or gel formulation in a plastic bag which dissolves in spray tank and releases contents	• Low applicator exposure during mixing, loading • Convenient for measuring • No container to dispose	• All quantities are premeasured and may not be the correct amount for the site

allowing the most resistant types to flourish. Using higher than normal rates, or lower than labeled rates, may make resistance develop faster.

- Pesticide combinations are generally used to increase the number of pest species controlled. Using combinations will slow the development of resistance only in those pests that both pesticides control. The species controlled by only one of the pesticides can develop resistance as rapidly as if one pesticide were used alone. Use pesticides with two different modes of action.

PESTICIDE FORMULATIONS

Pesticide formulations are the finished, ready-to-mix or **ready-to-use** (**RTU**) products which contain the active ingredient plus various “other” or inert ingredients. The latter are used to improve the performance of the pesticide by affecting characteristics such as handling, persistence on foliage, safety, ease of application, and ability to mix with water.

The formulation of a pesticide will dictate which type of application equipment to use.

Some formulations are ready for use. Others must be further diluted with water or a petroleum-based solvent by the user before they are applied.

A single active ingredient is often sold in several formulations. If you find that more than one formulation is available for your pest control situation, you must choose the best one for the job. Remember, all formulations are not labeled for all uses.

Formulation types can be divided into solids, liquids, gases, and pesticides sold in a certain type of packaging. See Summary of formulation types, page 53.

Adjuvants

Adjuvants are additional ingredients which can be mixed with pesticide spray mixtures to reduce the number of fine droplets and thereby decrease drift, increase the effectiveness of the active ingredient, and make application easier. Most pesticide formulations contain at least a small percentage of adjuvants. Always read the pesticide label before adding an adjuvant to a pesticide mixture to make sure it is legal and safe.

Common types of adjuvants

Surfactants (surface active ingredients) are a class of adjuvants that includes spreaders and stickers that change the surface tension of the spray solution. When the surface tension of the spray solution is reduced, spray droplets are more likely to remain on leaves without bouncing or rolling off. They also spread over a greater area on the leaves, which aids in absorption. Surfactants are most commonly used to apply pesticides on plants with very waxy or hairy leaves. Always check that the surfactant is approved for aquatic uses.

Synergists can increase the activity of pesticides by blocking the pest’s ability to break the chemical down into a harmless compound.

Buffers adjust the pH of the spray mixture to decrease the breakdown of pesticides that occurs from exposure to alkaline water conditions.

ADDITIONAL RESOURCES

National Pesticide Information Center (NPIC). Oregon State University, 333 Weniger Hall, Corvallis, OR 97331-6502. 800-858-7378. http://npic.orst.edu. *Information about pesticides and pesticide-related topics.*

The Pesticide Book, 6th edition. G.W. Ware and D.M. Whitacre. MeisterPro Information Resources: 2004. *Information about pesticide chemistry, mechanisms, and modes of action.*

Fundamentals of Weed Science, 2nd edition. R. L. Zimdahl. Academic Press: 1998. *An extensive overview of weeds and their management.*

Weed Science: Principles and Applications, 3rd Edition. W.P. Anderson. Brooks Cole: 1995. *Information on weeds and weed control.*

Herbicide Resistance Action Committee. www.HRACglobal.com. *Information on the resistance of herbicides.*

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education.* *See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos.* *See page 2.*

PROTECTING THE ENVIRONMENT

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Understand pesticide drift and how to minimize it

B. Know the factors that contribute to soil persistence

C. Know the ways a pesticide can move out of the target area

D. Describe how non-target organisms are affected by pesticides

E. Know how to prevent pesticides from contaminating groundwater

F. Describe the general environmental protection procedures

INTRODUCTION

The application of pesticides to aquatic environments is a delicate and potentially harmful operation. Because waterways are interconnected, a pesticide applied in one lake could spread throughout the watershed, negatively affecting plants, animals, and humans outside the targeted area. Pesticide applicators must be aware of the risks associated with applying pesticides to water and must be willing to take steps to prevent the contamination of the water supply and toxic effects on plants and animals.

Aquatic pesticide application is very different from other application types. Usually, we want to keep pesticides out of water sources. With aquatic applications, the most important thing is to keep the pesticide in the water within the application site.

Pesticides can move outside of the target area by several means:

- **spray drift,**
- water movement,
- **leaching,**
- volatilization, and
- on contaminated equipment.

Movement outside the target area can have toxic effects on fish, plants, **pollinators**, and humans downstream.

SPRAY DRIFT

This term refers to pesticide movement through the air to areas not intended for treatment. It presents a potential hazard to sensitive vegetation, wildlife, people, livestock, and aquatic areas next to treated areas. Movement of pesticides away from the target can be a costly problem facing pesticide applicators. Drift damage also may result in fines, loss of certification, and lawsuits.

Vapor drift

In addition to droplet (physical) drift, certain pesticides **volatilize** (change to gaseous form), producing fumes off the plant or soil surfaces that may cause damage. **Vapor drift** has the potential to travel further distances than **particle drift** if the right climatic conditions exist. For volatile pesticides, this potential increases as temperature increases. **Temperature inversions** may also contribute.

Particle drift

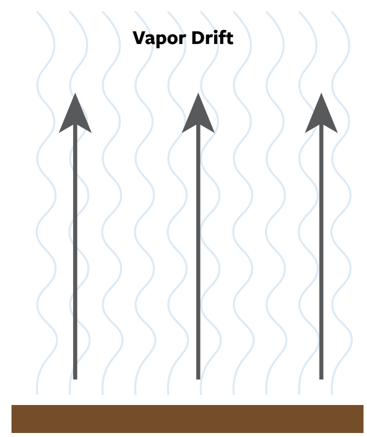
Any pesticide can drift. When pesticides are applied as sprays, air currents acting on the suspended spray droplets can carry some spray through the atmosphere beyond the intended target. Particles smaller than 150 microns (size of fog or mist) present the greatest drift hazard. Several factors affect the direction, distance, and amount of spray drift:

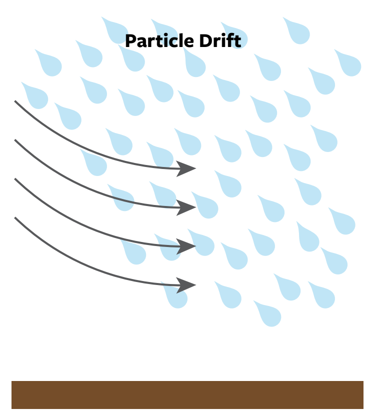
- application equipment (**nozzle** type, pump pressure)
- size of the droplets
- boom height
- type of spray (invert oil or water based)
- spray additives
- wind direction and velocity
- temperature inversions (when warm air traps a layer of cool air near the ground)

To reduce the chances for drift, take the following precautions:

- Use the lowest practical pressures.
- Leave an untreated edge (**buffer zone**).
- Angle nozzles toward the ground.
- Use nozzles with the largest practical openings to increase droplet size.
- Use low-volatile formulations of the chemicals.
- Spray when wind speed is low.
- Do not spray during a temperature inversion.
- Spray when sensitive vegetation is not actively growing.

High temperature and low relative humidity may cause spray droplets to rapidly evaporate into smaller droplets that are more likely to drift. Even if no wind is obvious, temperature inversions combined with slight air currents can result in substantial drift of fine droplets. Fine herbicide droplets or vapor can remain suspended in the cool air for long periods and can drift with slight breezes or move downslope. Read and follow drift precautions stated in the "Environmental Hazards" and "Directions for Use" sections on the product label.





CONTAMINATED EQUIPMENT

Do not use spray equipment contaminated with pesticides from previous applications. Always use the triple rinse procedure described on p. 48. To minimize contamination problems, consider dedicating one sprayer only for a particular use and another sprayer for another use.

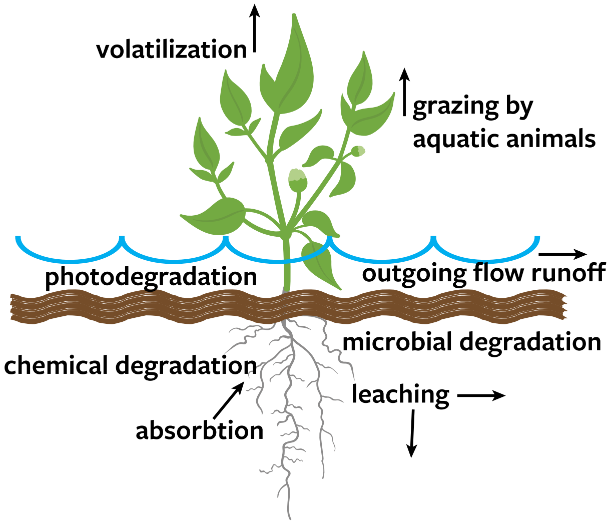
Thoroughly clean, maintain, and calibrate all application equipment regularly so it will be accurate and dependable. The application equipment you use can greatly affect weed control. Check hoses and pumps for leaks. Inspect nozzles and shut-off valves to make sure they work properly. Do not allow suspension solutions to stand for any length of time in a sprayer without constant agitation. They will settle out and solidify in the bottom of the tank and hoses, making reagitation or cleaning difficult.

PESTICIDE PERSISTENCE

Persistence refers to the length of time a pesticide remains in the environment. This depends on how quickly it breaks down or degrades, which is largely a function of its chemical composition and the environmental conditions. Persistence is usually expressed as the “half-life” of a pesticide. The half-life of a pesticide is the amount of time required for half of the pesticide to become inert. Pesticide half-lives range from just hours to years. The following factors affect pesticide persistence:

Microbial degradation

When soil microorganisms such as bacteria and fungi use pesticides as part of their food supply, they decompose or break down the chemicals. Some pesticides are degraded rapidly (easily used by the microorganisms), whereas others resist degradation. Some pesticide uptake and degradation by microbes is passive, meaning that the pesticide is not really used as a food source.



Different pathways through which a pesticide may leave a system.

Chemical degradation

Some pesticides break down through natural chemical reactions. Chemical degradation generally involves reactions such as oxidation, reduction, and hydrolysis. pH often influences the rate of chemical degradation. Many aquatic herbicides are broken down through photodegradation, or hydrolysis driven by UV light from the sun.

Absorption to soil and organic matter

Soil texture also influences the persistence of a pesticide. Soil particles and organic matter can tie up the herbicide and make it less available for absorption by plants; this process is called adsorption.

Removal by plants

Plants absorb and subsequently metabolize many pesticides, removing them from the system. When animals or fish graze these plants, the compounds are further removed from the system.

pH

The acidity or alkalinity (pH) of the soil affects persistence and **solubility** of some pesticides. Alkaline conditions enhance the persistence of some pesticides, while acid conditions affect the persistence of others.

AQUATIC TOXICOLOGY

Aquatic toxicology is the study of the effects of environmental contaminants on aquatic organisms, such as the effect of pesticides on the health of fish or other aquatic organisms. A pesticide's capacity to harm fish and aquatic animals is a function of its toxicity, exposure time, dose rate, and persistence in the environment.

Toxicity of the pesticide refers to how poisonous it is. Some pesticides are extremely toxic, while others are relatively nontoxic. See more specific information on page 23.

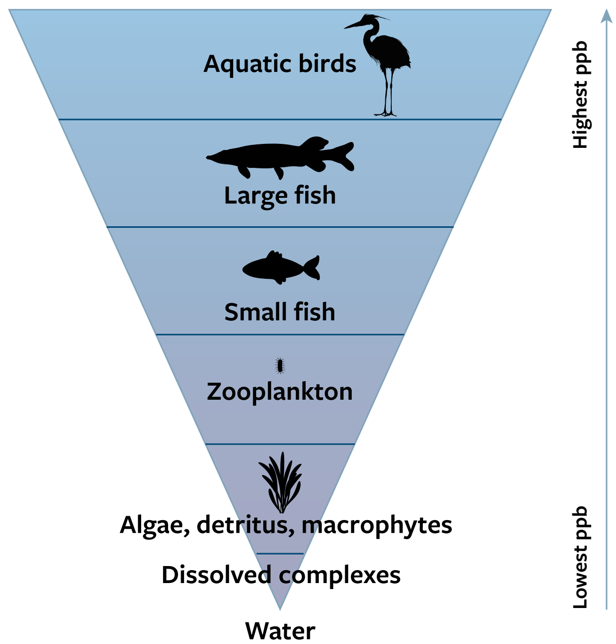
Exposure refers to the lengths of time the animal is in contact with the pesticide. A brief exposure to some chemicals may have little effect on fish, whereas longer exposure may cause significant harm.

Dose rate refers to the quantity of pesticide to which an organism is subjected, either through oral, dermal, or inhalation exposure. A small dose of a more toxic chemical may be more damaging than a large dose of a less toxic chemical. Dosages can be measured as the weight of toxicant per unit of body weight (this is usually expressed as milligrams of pesticide per kilogram of body weight), or as the concentration of toxicant in the water or food supply (this is expressed as parts per million or parts per billion).

Exposure of fish and other aquatic animals to a pesticide depends on its biological availability, **bioconcentration**, **biomagnification**, and persistence in the environment. **Bioavailability** refers to the amount of pesticide in the environment available to fish and wildlife. Some pesticides break down rapidly after application. Some bind tightly to soil particles suspended in the water column or to stream bottoms, thereby reducing their availability. Some are quickly diluted in water or rapidly volatilize into the air and are less available to aquatic life.

Bioconcentration or **bioaccumulation** is the accumulation of pesticides in animal tissues at levels greater than those in the water or soil to which they were applied. Some fish may concentrate certain pesticides in the body tissues and organs at levels 10 million times greater than in water.

Biomagnification is the accumulation of pesticides at each successive level of the food chain. At each step in the food chain, the concentration of pesticide increases.



Biomagnification occures as pesticides or other substances make their way through the levels of the food chain.

Sublethal effects

Not all pesticide poisonings result in the immediate death of an animal. Small sublethal doses of some pesticides can lead to changes in behavior, weight loss, impaired reproduction, inability to avoid predators, and lowered tolerance to extreme temperatures. The overall consequences of sublethal doses of pesticides can be reduced adult survival and reduction of the population.

Habitat alteration

Pesticides can reduce the availability of plants and insects that serve as habitat and food for fish and other aquatic animals. Insect-eating fish can lose a portion of their food supply when pesticides are applied. A suddenly inadequate supply of insects can force fish to range farther in search of food, where they may risk greater exposure to predation.

Spraying pesticides can also reduce reproductive success of fish and aquatic animals. The shallow, weedy nursery areas for many fish species provide abundant food and shelter for young fish. Spraying herbicides near weedy nurseries can reduce the amount of cover and shelter that young fish need in order to hide from predators and to feed. Most young fish depend on aquatic plants for refuge in their nursery areas.

Aquatic plants provide as much as 80% of the dissolved oxygen necessary for aquatic life in ponds and lakes. Spraying herbicides to kill all aquatic plants can result in severely low oxygen levels and the suffocation of fish. Using some herbicides, especially fast-acting contact or non-selective herbicdes, to completely clean up a pond can significantly reduce fish habitat, food supply, dissolved oxygen, and productivity.

Pesticides may be toxic to birds as well. Pesticides may result in bird kills if birds ingest granules; are exposed directly to the spray; drink and use contaminated water; or feed on pesticide-contaminated prey.

As with all pest control efforts, your goal should be to reduce the pest problem to acceptable levels, not necessarily to eradicate the pest. Eradication can upset the ecosystem's balance and may have detrimental effects far beyond the control of the pest itself.

Aquatic pesticide labels often contain information about application techniques, rates, possible fish kills, fishing restrictions, drift precautions, and waiting periods. Always read the label carefully and follow these directions.

Fish and animal exposure

Fish and aquatic animals are exposed to pesticides in three primary ways:

- dermally—direct absorption through the skin while swimming in pesticide-contaminated waters,
- breathing—direct uptake of pesticide through the gills during respiration, and
- orally—drinking pesticide-contaminated water or feeding on pesticide-contaminated prey.

Poisoning by consuming another animal that has been poisoned is called secondary poisoning. For example, fish feeding on dying insects poisoned by insecticides may themselves be killed if the insects they consume contain large quantities of pesticides or toxic byproducts.

Invertebrates

Most aquatic herbicides are nontoxic to invertebrates when used at or below recommended rates. Any toxic effects that are found are usually short-lived, because the high reproductive rates of invertebrates allow populations to recover rapidly. However, indirect effects may be important as well.

For example, when herbicides are used properly, applications result in decaying plant material. Decomposition reduces the amount of dissolved oxygen in the water column, which may have adverse effects on aquatic invertebrates and other organisms that rely on dissolved oxygen for respiration.

Reduced weed cover may also decrease invertebrate populations. However, the same increase in decaying organic material may increase invertebrate food sources, which will cause them to increase in number.

Usually, a herbicide treatment will result in increased invertebrate individuals, but will decrease the number of species present. This is because only those species tolerant of reduced oxygen, harborage, and water quality will be able to survive. This shift in population will likely be undesirable. High quality aquatic ecosystems are characterized by high species diversity, with low numbers of each species.

You should monitor the impacts of your pest management tactics. Remember that your aquatic site is an interconnected system, and that your actions will affect far more than just your target pest.

HARMFUL EFFECTS ON NONTARGET PLANTS AND ANIMALS

Despite the advantages of pesticides, the problems associated with their use have been well documented. These include the resurgence of pest populations after decimation of their natural enemies, development of pesticide-resistant populations, and negative impacts on nontarget organisms both within and outside the crop system.

Nontarget organisms may be harmed by pesticides in two ways:

- direct contact, and
- contact with residues.

Harmful effects from direct contact

Pesticides may harm nontarget organisms present during application. Pesticides may harm wildlife or insects, too. Even tiny amounts of some pesticides can harm them or destroy their food source. Read the warnings and directions on the pesticide labeling carefully to avoid harming nontarget organisms during a pesticide application.

Harmful effects from residues

A residue is the part of a pesticide remaining in the environment after an application or spill. Pesticides usually break down into harmless components after they are released into an environment. The breakdown time ranges from less than a day to several years. The rate of pesticide breakdown depends mostly on the chemical structure of the active ingredient in the pesticide. The rate of breakdown also may be affected by environmental conditions at the release site, such as:

- presence of microorganisms,
- temperature, and
- exposure to direct sunlight.

When using persistent pesticides, consider whether their continued presence in the environment is likely to harm people, plants, or animals, possibly through bioaccumulation. When the same mixing and loading site or equipment cleaning site is used frequently without taking steps to limit and clean up spills, pesticides are likely to accumulate in the soil. When this occurs, plants, animals, and objects that come into contact with the soil may be harmed. There is also a higher likelihood that the pesticides will move offsite and contaminate the surrounding environment or move into surface water or groundwater.

GENERAL ENVIRONMENTAL SAFETY PROCEDURES

Follow these guidelines to prevent environmental damage:

- Use IPM. Minimize pesticide use by utilizing other pest management practices to reduce or eliminate pesticide use.
- Select pesticides carefully. Read pesticide labels carefully to choose the best pesticide for your situation.
- Follow pesticide label directions. Container and supplemental pesticide labels are the law. Labels provide crucial information about application rates, timing, and placement of the pesticide. Consult all labels before using the pesticide.
- Calibrate accurately. Calibrate equipment carefully and often to avoid over or underapplication.

- Measure accurately. Carefully measure concentrates before placing them into the spray tank. Do not add a little extra to ensure that the pesticide will do a better job.
- Avoid back-siphoning. Make sure the end of the fill hose remains above the water level in the spray tank at all times. This prevents back-siphoning of the pesticide into the water supply. Use an anti-backflow device when siphoning water directly from a well, pond, or stream. Do not leave your spray tank unattended.
- Poor mixing and loading techniques, such as mixing too close to a water source or well, tank overflow, and lack of anti-backsiphon devices on water fill lines can lead to contamination.
- Consider weather conditions. If you suspect heavy rain will occur, delay applying pesticides.
- Mix on an impervious pad. Mix and load pesticides on an approved impervious mixing and loading pad where spills can be contained and cleaned up. If mixing in the field, change the location of the mixing area regularly.
- Dispose of wastes and containers properly. All pesticide wastes must be disposed of in accordance with local, state, and federal laws. Triple-rinse or pressure-rinse containers. Pour the rinse water into the spray tank for use in treating the labeled site. After triple rinsing, perforate the container so it cannot be reused. Recycle all metal and plastic triple-rinsed containers. Otherwise, dispose of them in a state-licensed sanitary landfill.
- Store pesticides safely and away from water sources. Pesticide storage facilities should be situated away from wells, cisterns, springs, and other water sources. Pesticides must be stored in a locked facility that will protect them from temperature extremes, high humidity, and direct sunlight. The storage facility should allow for easy containment and cleanup of pesticide spills and be made of materials that will not absorb any pesticide that leaks out of a container. Store only pesticides in the facility, and always store them in their original containers.

ADDITIONAL RESOURCES

Department of Agriculture Pesticide Programs.
This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education. *See page 1.*

State Pesticide Safety Education Programs.
These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos. *See page 2.*

APPLICATION AND CALIBRATION

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Understand and describe different types of application techniques

B. Understand application timing

C. Describe different types of application equipment

D. Describe the components of sprayers

E. Understand proper sprayer maintenance and storage

F. Define and understand how to conduct calibration

G. Determine application rates based on area, concentration, and percent active ingredient

H. Define compatibility and understand its importance in tank mixing

INTRODUCTION

Once you have begun to understand the biology and ecology of your aquatic management site and have come up with an IPM plan for your pest issues, you will need to decide what equipment is necessary for your management techniques. In addition, you will need to learn how to calibrate or adjust your equipment so that the correct, expected amount of pesticide is applied.

APPLICATION METHODS

The application method you choose depends primarily on the product. Other factors include the characteristics of the pest or site, available application equipment, and the relative cost and effectiveness of alternative methods. You will often have a choice between methods.

The principal objective with any application is to effectively bring the chemical into contact with the targeted pest without harming the environment.

The primary application methods for aquatic weed control are:

Handgun spraying

Handgun spraying of surface, emersed, and ditch-bank species. Most handgun nozzles provide a high flow rate, a straight stream, and a large droplet size to ensure coverage of the target vegetation with minimum drift.

Subsurface injection

Subsurface injection just below the water surface for submersed weed control. Hoses place the nozzle at the surface or just below it. The nozzle body should contain a disk that meters the flow into the water.

Bottom treatment

Bottom treatments, or deep-water injection, inject the pesticide into bottom water by connecting weighted brass pipes to hoses that extend from a boom on a spray boat. The herbicide is released into the water through small holes bored about 6 inches from the end of the pipe. For best results, pipes should be no more than 3 feet apart. Applicators often construct their own nozzles by drilling holes in a piece of galvanized pipe. These types of nozzles should be carefully calibrated. Application rates are based on the volume of the lower 2 feet of water. This technique is particularly effective early in the growing season when submersed plants are still short. It works best in lakes or still waters that have firm, sandy bottoms.

Bottom treatments can also be made using weighted **invert emulsions** or **polymers**. Inverts used in aquatic systems usually consist of spray droplets of water surrounded by oil. Because oil is added, the consistency of invert emulsions is like mayonnaise. When weighted with a copper compound, the solution sinks to the bottom and sticks to plants.

Aerial application

In **aerial applications** booms mounted on fixed-wing aircraft or helicopters usually use hollow cone or flat fan nozzles to improve coverage with the smaller volume of spray solution applied per acre. Often, a microfoil boom is used to produce large droplets at low pressure.

Foliar spraying

Foliage or **foliar spraying** is an application of a liquid herbicide to leaves and stems. It is the most visible type of application and is the most subject to drift.

Volume treatment

Volume treatments treat the total or partial volume of a body of water. This method is often recommended for the control of microscopic or filamentous algae, and submersed plants. Liquid pesticides are usually diluted in water in a tank to facilitate even distribution. The solution is sprayed on the surface of the water and allowed to sink to the bottom, or injected below the water surface. Volume treatments must take into account surface area and average depth of water; this measure is usually expressed in **acre-feet** (a.f.).

Broadcast treatment

Broadcast treatment, or **blanket application**, is a uniform treatment of an entire area.

Spot treatment

Spot treatments are applied to a localized or restricted area, usually to control a small weed infestation requiring special attention. Nonselective or residual herbicides sometimes are used on perennial weed infestations to prevent their spread. Spot treatments are usually made using broadcast, bottom, or granular treatments. Granules are usually applied using a granular spreader, and granules will sink to the bottom of the water body.

Band treatment

Band treatment usually means treating a strip. This reduces chemical cost because the treatment band covers less area than a broadcast application. It is also used with mechanical controls.

Soil application

Soil application is the application of liquid or granular soil active residual herbicides to the soil for control of unwanted vegetation; this is a method used only during winter drawdown. Soil applied herbicides range in residual activity from zero to several years. Soil applications are most commonly used for aquatic weed control in dewatered irrigation canals, or seasonally dry areas of reservoirs.

Soil applications are applied in spots or broadcast over large areas by a variety of equipment. This application requires moisture to be moved into the root zone so herbicidal activity may be delayed. Soil application may not be effective in dry areas. In addition, it requires complex knowledge of proper and effective planning and application.

With soil application, consideration must be given to the potential for the herbicide to move away from the site during periods of high rainfall and winds.

TREATMENT OF FLOWING WATER

Making applications to flowing water systems may require permission from riparian areas along the entire system that will be treated. Check with local authorities for regulations specific to your area.

Flowing water in ditches and canals requires control techniques different from those used in lakes, ponds, or other static systems. Pesticide solutions are usually injected or allowed to drip into the water via constant-flow metering devices; the water will disperse the pesticide itself. The dosage rate on the pesticide label is usually given as the amount of herbicide per hour per cubic feet per second (CFS), a measure of water volume and velocity. You can roughly calculate CFS with the following equation:

CFS = average stream width × average stream depth × velocity in feet per second × 0.9

0.9 is a correction factor for the velocity measurement. Take this measurement at the surface.

A dry concentrate can be applied in large volumes with this treatment, because the concentration will decrease as the water moves the pesticide downstream. This procedure is most commonly used with copper sulfate for algae control.

Re-treatment

Most aquatic herbicides are not persistent compounds. This characteristic is desirable because it means that restriction periods on the use of water can be fairly short. However, limited persistence also means that undesirable vegetation can regrow in an area soon after treatment, either from plant parts not killed by the treatment or from roots, seeds, spores, or other plant parts.

Algae must often be re-treated several times per season, whereas flowering plants usually require at most a follow-up treatment to kill missed or late-sprouting plants. **Re-treatment** of a site is typical during a single growing season. However, the species targeted with subsequent applications may not be the same as those treated early in the season. Applications may continue throughout the growing season as different species emerge.

EQUIPMENT

Most aquatic pesticide application equipment is similar to agricultural application equipment. However, most equipment can be adapted to aquatic situations, such as applying from a boat or injecting pesticides into deep water.

Your choice of application equipment is just as important as the pesticides you choose. Many problems, such as pesticide drift, irregular coverage, or failure of the pesticide to reach the target, are related to the equipment used. The function of any application equipment is to deliver the proper rate of chemical and to apply it uniformly over the target area.

When choosing equipment ask:

1. Will it apply the pesticide effectively?
2. Will the application cause excessive drift?
3. Will it do the job at a reasonable cost?
4. Is it easy to operate and clean?

Selecting proper application equipment depends on the type of application. Equipment choice depends on site working conditions, pesticide formulation, the type of area to be treated, and possible problems. While large power-driven equipment may be desirable for some jobs, other jobs are best done by small portable or hand-held equipment.

Most application equipment falls into two groups depending on the type of formulation dry or liquid. Most aquatic pesticides are formulated for liquid application. In addition, you may be limited by the type of vehicle you are using; whether it is a boat with an inboard or outboard motor, an airboat, or some type of aircraft.

Equipment for dry applications

Granular applicators apply coarse, dry, uniformly sized particles to the soil or lake bottom. Several types of dry spreaders exist; pneumatic whirling disks, as in seeders and fertilizer spreaders, multiple gravity feed outlets such as lawn and fertilizer spreaders, multiple air-driven feed outlets, and ram-air (used in aircraft). Some applications use shaker cans and hand distribution of pellets.

Although they vary greatly in design, granular applicators normally consist of a **hopper** to hold the pesticide, a mechanical-type **agitator** at the base of the hopper to provide a uniform and continuous feed, drop tubes, and some type of metering device, usually a slit-type gate to regulate the granule flow.

The metering device must function properly. Clean it regularly to remove caked material or other obstructions. Check the condition of all components and replace them if they appear worn. Badly worn components may result in large application errors. Check the tubes and diffusers for leaks or blockage. Drop tubes or hoses should allow the material to fall freely without collecting in the tube.

In most aquatic applications, granular formulations are applied using a bow-mounted centrifugal or blower-type spreader. Normally, the spreader is purchased as a complete unit except for the mounting system, which is usually designed to allow quick removal, since boats are used for both granular and liquid applications. Blower-type spreaders use air pressure to propel the granules. One advantage of this type of spreader is that less dust is created in comparison to centrifugal spreaders.

This method allows the treatment of a wide swath and requires no structure extending beyond the sides of the boat. One disadvantage is the amount of material that must be handled, usually 20–400 lb/acre depending on the pesticide.

Liquid application equipment

Many pesticides are applied as liquids with sprayers. Sprayers vary in size and type from hand-operated units to machines with 100–foot booms. Some apply dilute pesticide mixtures, while others apply concentrates. Most use low pressure (< 40 psi) and low volume. Some apply spray through single outlets or nozzles, while others use multiple nozzles linked by sections of pipe or tubing to form a boom or spray head. The principal types used for pest control are discussed below. Variations or combinations of these types also exist.

Hydraulic sprayers

Hydraulic sprayers make spot, band, or broadcast treatments. The spray solution is forced through the spraying system under pressure by either a pump or compressed gas and released on the target area. The sprayer may have one or several nozzles on a boom or in a cluster. The nozzles may be permanently mounted or handheld. Hydraulic sprayers are usually powered and can be towed, self-propelled, or mounted on other equipment, including aircraft. However, for small jobs, a hand-carried compressed air or **backpack sprayer** is often most effective.

A hydraulic sprayer uses water, oil, or a mixture of these to carry the pesticide. The desired application rate is specified by pressure and travel speed.

Low-pressure sprayers operate at pressures of 10–80 psi. They use roller or centrifugal pumps.

Backpack sprayers

Backpack sprayers consist of a tank, a pump, and a spray wand with one or more nozzles. A backpack sprayer is carried on the operator's back. The weight of the tank should be supported across both shoulders to prevent fatigue. Most backpack sprayers use hand pumps. However, some units have a small battery or engine-powered pumping system. Regardless, consistent and uniform pressure control is essential to ensure proper application. Some sprayers have a pressure-regulating valve or a **pressure gauge** to help the user maintain desired pressure.

Tank capacity is usually 3–5 gallons. Small size, portability, and ease of use make the backpack sprayer a valuable tool for many users. Backpack sprayers are best suited for small acreages, spot spraying, hard-to-reach areas, and other areas where a larger sprayer is impractical.

Boat application

Aquatic pesticide application boats should be operated by an application team of at least 2 people. The team can safely share the responsibilities of monitoring application rates. One person can drive the boat, monitor and set boat speed, and monitor the dispersal or application rate. The other person would be responsible for filling the spray tank or granular pesticide spreader hopper, directing the spray wand or handgun, and ensuring that the spray or spreading equipment is operating properly.

In order for the team to be effective, the equipment must be calibrated correctly.

Aerial application

You can apply pesticides aerially using either an airplane or a helicopter, although most applicators use airplanes. Airplanes are fast, maneuverable, and have a large payload capacity per dollar invested. Helicopters are even more maneuverable, can be operated over a range of speeds, and may be operated in almost any area because a landing strip is not needed. However, helicopters are more expensive to operate per unit of flying time, so the pilot must minimize the time lost in turnarounds and refilling.

Liquid dispersal systems are the most widely used in pesticide application aviation. They consist of a hydraulic circuit, including a tank, pump, hose, pressure gauge, boom, screens, flow regulators, and nozzles. Dispersal systems may be wind driven or powered directly from the aircraft engine.

Application of pesticides from airplanes is regulated by the Federal Aviation Administration (FAA). FAA judges the flying ability of pilots and the safety of their aircraft. FAA rules also state that an aerial applicator may not apply any pesticide except as the label directs.

Sprayer design

Liquid applications to aquatic systems are usually made in one of two ways: either by a tank mix method or by direct metering into pump suction. The tank mix design consists of a large tank in which water and chemicals are mixed by the applicator. **Tank mix sprayers** are relatively cheap and easy to operate; however, they are only practical in aquatic sites for small areas. **Direct injection sprayers** are much more efficient and accurate.

Injection differs from conventional spraying because the chemical is not mixed in the spray tank. Injection sprayers have a main tank that contains only water, while a second tank holds the chemical. Special pumps meter precise amounts of the chemical into the line that carries water to the booms. In injection sprayers, there is no leftover tank solution at the end of the job. Time-consuming mixing and cleaning activities are eliminated. Electronic controls are used to measure the flow of water and inject the proper quantity of chemical into the water stream before it is delivered to the nozzles.

This design reduces contamination potential and eliminates the need for tank agitation. Direct injection systems can be set up to accommodate more than one chemical at a time. Each chemical requires a separate pump and a closed-system tank.

Sprayer designs also include both boom and boomless units to match a wide range of applications.

Sprayer components

It is important to be familiar with the various components of your spray application equipment, so you can identify any problems and understand how your equipment works.

Tanks

Sprayer tanks must allow easy use, cleanup, and maintenance. They must be made of material that resists corrosion from various formulations. Suitable tank materials include polyethylene fiberglass and stainless steel. Be sure to select a tank that is compatible with the pesticides used. For example, polyethylene tanks cannot be used with ammonium phosphate solutions because ultraviolet light causes polyethylene to break down. Fiberglass tanks may be affected by certain types of solvents. Some pesticides will corrode aluminum and galvanized steel tanks.

Tanks should:

- have large openings for easy filling and cleaning,
- allow straining during filling,
- allow for mechanical or hydraulic agitation
- have a large drain,
- have a gauge to show the liquid level (protect gauges to prevent breakage),
- have a cutoff valve for storing liquid, pesticide temporarily while other parts are being serviced, and
- have outlets sized to the pump capacity.

Pumps

Pumps must be large enough to supply the volume needed for the nozzles and to the hydraulic agitator (if necessary), and to maintain the desired pressure. The pump parts should be able to resist corrosion and abrasion if abrasive materials like wettable powders are used. Select gaskets, plunger caps, and impellers that are resistant to swelling and chemical breakdown caused by some liquid pesticides. Consult your dealer for available options.

Pump capacity is measured in **gallons per minute** (**GPM**) or **gallons per hour** (**GPH**). Select a pump with a capacity at least 50% larger than the sum of the nozzle outputs and the agitator. Oversizing the pump compensates for wear and keeps the system running longer.

Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. Pumps can be damaged if run dry or if they have a restricted inlet or outlet. Pumps depend on the spray liquid for lubrication and removal of friction heat.

Common types of pesticide sprayer pumps are roller, centrifugal, piston, and diaphragm. Each has unique characteristics and is suited to a particular use.

Agitators

Agitators mix the components of the spray mixture uniformly and, with formulations like wettable powders, keep the material in suspension. Wettable powders must be agitated in the spray tank because they will settle out on the bottom without proper agitation. If agitation is inadequate, the actual application rate of the pesticide may vary as the tank empties. Use of an emulsion also requires occasional agitation of the spray mixture. The two common types of agitators are hydraulic and mechanical.

Strainers

Strainers filter the spray mixture to protect the working parts of the spraying system and prevent scales, rust flakes, or other foreign material from clogging nozzle tips. As the mixture moves through the system, strainer openings should be progressively smaller. Strainer mesh is described by the number of openings per linear inch; a high number indicates a fine screen. Place strainers 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.

Hoses

Hoses should be made of weather-resistant synthetic rubber or plastic. They should have a burst strength greater than peak operating pressures and resist oil solvents present in pesticides and adjuvants.

Hose size should be matched to the flow volume and pressure requirements. If the hose in the pump suction line is too small, the pump may not get enough pesticide mixture. If the hose in the pressure line is too small, volume at the nozzles will be insufficient.

Keep hoses from kinking or being rubbed. Rinse them often, inside and out, to prolong hose life. Store them out of the sun. Replace hoses at the first sign of surface deterioration. Make sure hose fittings are free of leaks. Frequently inspect all hoses and fittings.

Pressure gauges

Pressure gauges monitor your spraying system and tell you how much pressure the system is using. They must be accurate and have the range needed for your work. For example, a 0–100 psi gauge with 2-lb graduations is adequate for most sprayers. A high pressure gauge will not give an accurate reading of a low-pressure sprayer. Check frequently for accuracy, and mount the gauge so it can be seen easily. If the gauge does not zero properly, replace it.

Pressure regulators

Pressure regulators control the pressure, and indirectly, the quantity of spray material delivered by the nozzles, because decreasing pressure will increase the droplet size being released from the sprayer. They protect pump seals, hoses, and other sprayer parts from damage due to excessive pressure. Pressure relief valves maintain a constant pressure despite changes in engine speed.

Control valves

Control valves are all valves other than the pressure regulator that regulate the flow of liquid. These control valves vary from a single valve that shuts off all flow to multiple valves for individual outlet controls. Make sure quick-acting cutoff valves are located between the pressure regulator and the nozzles to provide positive on-off action. Have cutoff valves that stop all flow in any section of the spraying system within easy reach of the sprayer operator. Check valves periodically to ensure proper performance.

Nozzles

Nozzle tips break the liquid pesticide solution into droplets. They also distribute the spray in a predetermined pattern and help control the application rate.

Nozzle patterns come in three basic types: solid stream, fan, and cone. Check with the nozzle manufacturer's literature for the best nozzle for your job. Nozzles should be able to resist corrosion and abrasion if abrasive materials are used. Be certain that all nozzles are the same and replace worn nozzles. The best way to check for wear is to calibrate each nozzle.

A number of spray monitors detect system errors or failure. Nozzle monitors sense the flow at each nozzle. If the flow changes at a nozzle, a warning buzzer or flasher goes off. System monitors sense the operating conditions of the total spraying system. Sensors and microcomputers provide information such as travel speed, pressure, line flow, application rates, acreage, and gallons to empty. If something goes wrong, an alarm will sound.

Aquatic Nozzles

Many types of nozzles are used in terrestrial weed control; however, the constraints of aquatic application limit the variety of nozzles that can be used. The method of application, either submersed or subsurface, determines the type of nozzle that can be selected.

OPERATING AND MAINTAINING SPRAYERS

Properly operate and maintain spray equipment for safe and effective pesticide application. This will significantly reduce repair costs and prolong sprayer life, and this will also ensure effective, consistent pest control while minimizing chemical costs.

Before spraying

Thoroughly rinse the sprayer with clean water. Check gauges and the tank. Make sure nozzles are the appropriate type for the job. If using nozzles with check valves, make sure they are working properly. Check valves prevent dripping when flow to the nozzle drops below a certain pressure. Check the spraying system for leaks and output pattern.

If using a boom type sprayer, make sure the output of each nozzle differs by no more than 5% more or less than average. If it does, check screens, nozzles, hoses, etc. before changing that nozzle. If more than one nozzle varies by more than 5%, replace all the nozzles, because this strongly indicates excessive wear of the entire system.

Nozzle deviation can be determined fairly easily. Follow these three steps:

1. Measure the nozzle output by placing a bucket under each nozzle and catching the discharge for 1 minute's worth of operation.
2. Add these amounts together and calculate the average nozzle output.
3. Calculate percent deviation for each nozzle with the following formula:

$$\%\ \text{Deviation} = \frac{\text{average nozzle output} - \text{individual nozzle output}}{\text{average nozzle output}} \times 100$$

Precalibration checklist

- System is clean.
- Speed of travel is accurate.
- Strainers are in the proper location.
- Agitation is working properly.
- Nozzles are the appropriate size and type.
- Nozzle output is within 5% of rating.
- Nozzles are properly aligned and spaced.
- Boom is at correct height.
- Pressure gauge is accurate.
- Tank volume markings are accurate.

Make sure the tank is level during filling so that the gauge shows the amount in the tank correctly. Know the true volume levels of your equipment. Factory sight gauges and volume markers are often incorrect, resulting in miscalibration and misapplication.

During spraying

Check the pressure gauge and speedometer or tachometer frequently while spraying, making sure that the sprayer is operating at the same pressure and speed used when it was calibrated. Speeds should be reasonable so that sprayer booms are not bouncing or swaying excessively. Periodically check hoses and fittings for leaks. Check nozzles for unusual patterns. If emergency repairs or adjustments are necessary, always use adequate protective clothing, particularly rubber gloves. Use an old toothbrush to unclog nozzles instead of metal wire to unclog a nozzle; wire may distort the nozzle opening and change the spray pattern and output.

After spraying

To prevent chemical buildup, always flush the spray system with water inside and out after each use. Make the initial rinse of the inside of the tank at the application site. Apply the rinsate onto the site to reduce the generation and concentration of wastes at the clean-up area. You will need extra water on site with a saddle tank or truck.

Clean the inside and outside of the sprayer thoroughly before switching to another pesticide and before doing any maintenance or repair work. All equipment and equipment parts exposed to a pesticide will normally have some residue, including sprayer pump, tank, hoses, and boom.

Wear proper PPE to prevent skin contact with these residues.

Many pesticide labels have specific instructions for cleaning sprayers, because some tank cleaners work better on certain pesticides. If labels do not list specific cleaning directions, flush the sprayer tank, lines, and booms thoroughly with clean water and apply the pesticide-contaminated rinsate to labeled sites or use the rinsate in subsequent spray batches.

STORAGE OF SPRAYERS

Clean all sprayers thoroughly before storing for the season. The following guidelines should be followed before storing sprayers but can be done every time the sprayer is used.

1. Fill the sprayer to capacity with water, adding one cup of trisodium phosphate or household ammonia for every 10 gallons of water. If neither is available, use a strong detergent or soap. Some pesticides require additional cleaning (i.e., only ammonia will remove hormone-type (2,4-D) herbicides) these instruction can be found on the product label.
2. Wash the tank and pump parts thoroughly by running the sprayer for about 5 minutes with the spray boom off.
3. If possible, let the cleaning solution stand in the sprayer overnight. (Household ammonia will corrode aluminum sprayer parts, so do not allow it to sit overnight.)
4. Discharge the liquid from the tank, spraying some through the nozzles.
5. Drain the sprayer completely and remove nozzles, screens, and strainers.
6. Scrub all accessible parts with a stiff bristle brush.
7. Rinse the sprayer thoroughly inside and outside with clean water, and reassemble.

If storing the sprayer for the season, add 1–5 gallons (depending on the size of the tank) of lightweight emulsifiable oil to an equal volume of clean water. Flush the entire system with the oil-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, clean, and place all nozzles and screens in a dry place to prevent corrosion. Cover the nozzle openings in the sprayer boom with tape to keep dirt out. When storing for the winter, drain water from pumps, or it may freeze and crack the pump (if not stored in a heated building). As an added precaution to protect pumps, you may pour one tablespoon of radiator rust-inhibitor antifreeze into the pump inlet. Turn the pump several revolutions to coat the internal surfaces.

CALCULATIONS AND CALIBRATION

Calibration is simply determining the equipment delivery or application rate, or the amount of material delivered over a known area. The purpose of calibration is to ensure that your application equipment uniformly applies the labeled rate of product over a given area. If your equipment is not calibrated properly, you risk costly or even dangerous mistakes in the application of a chemical.

The effectiveness of any pesticide depends on the proper application and placement of the chemical. Too little pesticide results in poor pest control and a waste of money. Application of too much may result in damage to the desirable vegetation, environmental pollution, wasted money, and human health problems. Pesticide delivery rates can change with equipment wear, gauge error, nozzle wear, wheel slippage, and speedometer error.

Application equipment suppliers often provide charts and tables to help you determine how to set up your equipment and approximate desired delivery rates; however, such sources of information only estimate delivery rates. They cannot account for equipment wear and variations in gauges, speedometers, and plumbing. You must calibrate equipment to obtain more reliable determinations of equipment delivery rates.

You must make several decisions before every herbicide application:

1. Determine and possibly adjust the equipment delivery rate (calibrate).
2. Determine how much product is necessary for the job using the label.
3. Determine the appropriate amount of carrier for the amount of product to be used.

The product label, calibration, and your calculations will answer these questions.

To properly calibrate depending on the type of equipment, you may need a bucket marked in gallons, a scale, a stopwatch, tools, a container marked in ounces for nozzle output, a tape measure, and flags or stakes for marking distances. Unless your equipment is new, it probably has some pesticide residue in and on the various equipment components; therefore, wear PPE, including gloves. Finally, a pocket calculator will help reduce mathematical errors.

There are many methods of calibration; no single method is best for everyone or every situation. Any technique that provides accurate and uniform application is acceptable.

There are three common ways labels use to describe pesticide application rates:

1. Applications based on area.
2. Applications based on concentration.
3. Applications based on percent active ingredient.

Applications based on area

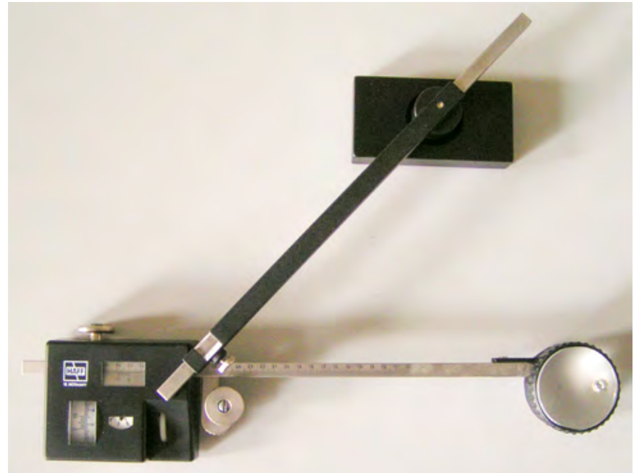
The area of your aquatic site can be measured and estimated in several ways. Small ponds can be measured with a tape measure, by pacing off (if you know your stride length) or with a **rangefinder**. When using a rangefinder, check frequently to make sure that it is measuring distances accurately.

On water, distances can be measured in several ways:

- Drag a floating rope of known length behind the boat. Drop a buoy at the rope's start, then drop another each time the end of the rope passes a buoy.

- Use a rangefinder.
- Use a map and a **planimeter.**
- Use a GPS or GPS-type software.

Once accurate distances have been measured and marked, boat speed (usually in feet per second) at a specific **RPM** (**revolutions per minute**) can be determined by timing the boat through any marked distance. Boat speed should be measured in two directions and averaged to allow for differences caused by wind or current. Subsequent distances can be estimated by operating the boat for the length of time equivalent to a desired distance.


A planimeter (also known as a planometer) is used to measure the area of a shape from its perimeter.[9]

Example:

Using the buoy method, you determine that a certain pond has a diameter of 600 ft. You drive your boat at 3000 RPM across the diameter line. It takes you 80 seconds (sec) to cross the lake.

$$\text{Speed of your boat at 3000 RPM} = \frac{600 \text{ ft}}{80 \text{ sec}} = 7.5 \text{ ft/sec}$$

You want to determine the length of another line across the pond. You drive your boat across the lake, and measure a time of 92 sec.

$$\text{Length of second line} = 92 \text{ sec} \times 7.5 \text{ ft per sec} = 690 \text{ ft.}$$

To estimate the acreage of small rectangular lakes or ponds, use the following formula:

$$\text{Surface acres} = \frac{\text{length in ft} \times \text{width in ft}}{43{,}560 \text{ sq ft per acre}}$$

Example:

What is the acreage of a rectangular pond that measures 800 ft by 440 ft?

$$\text{Surface acres} = \frac{\text{length in ft} \times \text{width in ft}}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Surface acres} = \frac{800 \text{ ft} \times 440 \text{ ft}}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Surface acres} = 8.1 \text{ acres}$$

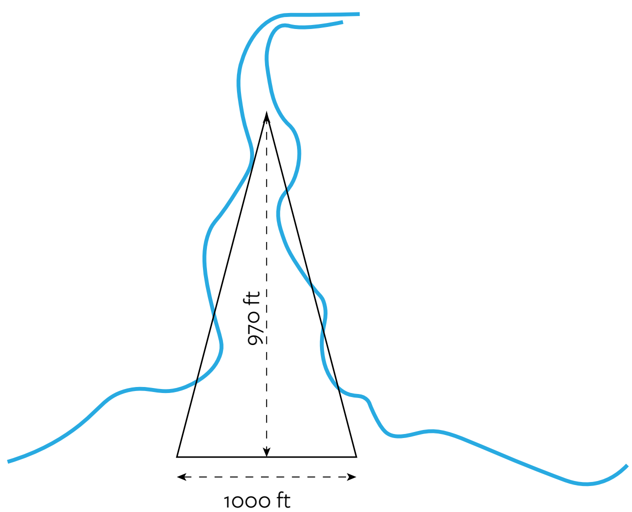
Many small lakes or coves are not rectangular, but may be more or less triangular or circular. The following equations determine the acreage of a triangle or circle.

$$\text{Acreage of a circular area} = \frac{3.14 \times \text{radius}^2}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Acreage of a triangular area} = \frac{1/2 \times \text{base} \times \text{height}}{43{,}560 \text{ sq ft per acre}}$$

Example:

Estimate the surface area, in acres, of the following cove with a base of 1,000 ft and height of 970 ft:



$$\text{Acreage of cove} = \frac{1/2 \times \text{base} \times \text{height}}{43{,}560 \text{ sq ft per acre}}$$

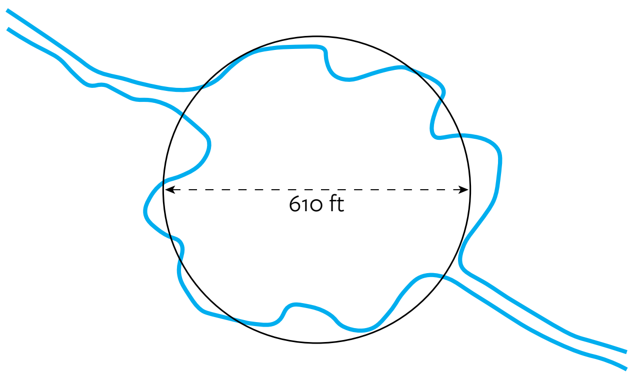
$$\text{Acreage of cove} = \frac{1/2 \times 1000 \text{ ft} \times 970 \text{ ft}}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Acreage of cove} = \frac{485{,}000 \text{ ft}}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Area of cove} \approx 11.14 \text{ acres}$$

Example:

Estimate the surface area, in acres, of the following pond with a diameter of 610 ft:



$$\text{Radius} = 1/2 \times \text{diameter}$$

$$\text{Radius} = 1/2 \times 610 = 305 \text{ ft}$$

$$\text{Acreage of pond} = \frac{3.14 \times \text{radius}^2}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Acreage of pond} = \frac{3.14 \times (305)^2}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Acreage of pond} = \frac{3.14 \times 93{,}025 \text{ ft}}{43{,}560 \text{ sq ft per acre}}$$

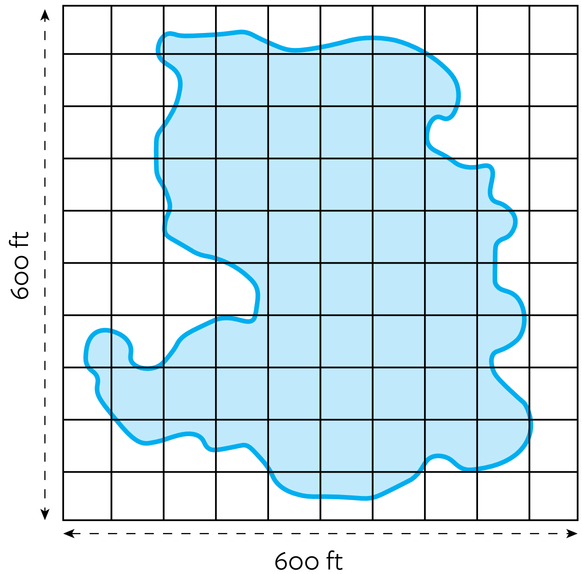
$$\text{Acreage of pond} = 6.7 \text{ acres}$$

The shapes of many lakes and ponds are irregular, and do not conform to any measurable geometric shape. In this case, area can be estimated with the following method:

- Inscribe a sketch of the lake inside a rectangle on graph paper.
- Measure the area of the rectangle.
- Estimate the proportion of the rectangle that is occupied by the lake. Do this by dividing the number of graph paper squares occupied by the lake by the total number of squares in the rectangle.
- Multiply the fraction you just calculated by the area of the rectangle. This will give you the lake's acreage.

Example:

Estimate the area of the following irregularly shaped lake:



Step 1:

$$\text{Area of a rectangle} = \frac{\text{length} \times \text{width}}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Area of a rectangle} = \frac{600 \times 600}{43{,}560 \text{ sq ft per acre}}$$

$$\text{Area of rectangle} \approx 8.26 \text{ acres}$$

Step 2:

The number of squares in the rectangle is 100, and the number of squares occupied by the lake is approximately 48. Therefore, the fraction of the rectangle occupied by the lake is:

$$48 \div 100 = 0.48$$

Step 3:

$$\text{Area of lake} = \text{area of rectangle} \times \text{fraction occupied by lake}$$

$$\text{Area of lake} = 8.26 \text{ acres} \times 0.48$$

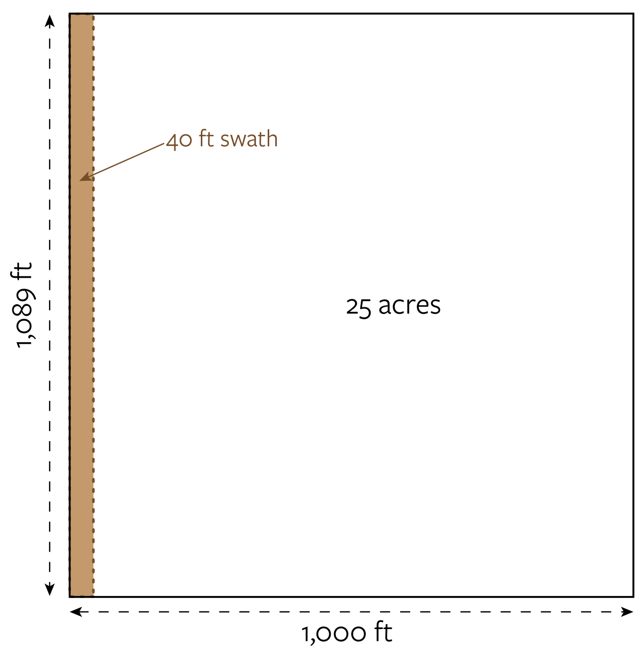
$$\text{Area of lake} \approx 4 \text{ acres}$$

Measuring large areas for herbicide application is easiest to do with rectangular shapes. Plots should be divided into subplots of smaller areas. For example, a 200-acre area could be marked in subplots of 25 acres or less, so that the application rate can be continually checked.

It may be helpful to lay plots out to conform to **swath width** so that a certain number of swaths will equal one acre. Dividing the swath width into 43,560 will tell you how long a one-acre swath would be. Using this as one dimension of the plot, you can calculate the other dimension by dividing the length of a one-acre swath into the area of the entire plot. In this way, you can redefine a dimension as a half-swath, two swaths, etc.

Example:

A pellet herbicide formulation is to be applied to a 25 acre plot in a large lake with a spreader that has a swath width of 40 feet. Show the rectangular plot layout that will allow each pass to treat 1 acre.



Step 1:

$$\text{Length of acre swath} = \frac{43{,}560 \text{ sq ft per acre}}{\text{swath width}}$$

$$\text{Length of acre swath} = \frac{43{,}560 \text{ sq ft per acre}}{40}$$

$$= 1{,}089 \text{ ft}$$

Step 2:

Determine the width of the plot:

Plot width = number of 1 acre swaths × swath width

Plot width = 25 × 40 = 1,000 ft

You can also calculate plot width by determining the total plot area of square feet and dividing by the plot length:

Area of plot = number of acres × 43,560 sq ft

Area of plot = 25 × 43,560 = 1,089,000 sq ft

$$\text{Plot width} = \frac{\text{total area}}{\text{plot length}}$$

$$\text{Plot width} = \frac{1{,}089{,}000}{1{,}089}$$

$$\text{Plot width} = 1{,}000 \text{ ft}$$

Pesticides often mix throughout the water column with the help of turbulence caused by the boat and other environmental factors. To ensure correct coverage, you will need to assume that the pesticide will diffuse between swaths, and you will need to define the effective swath as the distance between the centers of two adjacent treated swaths.

Example:

Show the rectangular plot layout that should be used when treating 25 acres with a liquid herbicide, using an 8-foot boom on alternate swaths, so that each pass will treat 1/2 acre.

Step 1: Determine effective swath width

Effective swath width = boom width × 2

Effective swath width = 8 × 2 = 16 ft

Step 2: Calculate the length of a 1/2 acre swath

$$\text{Length of swath} = \frac{1/2 \times 43{,}560 \text{ sq ft per acre}}{\text{effective swath width}}$$

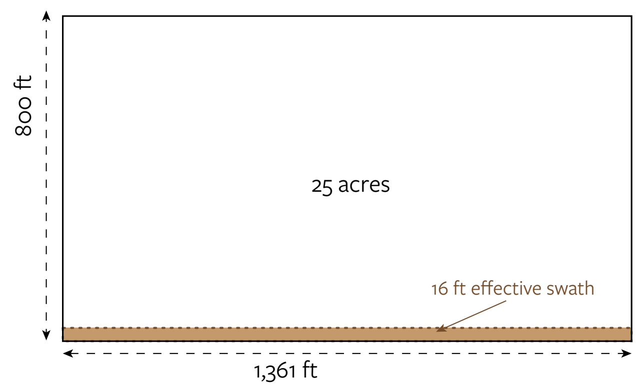
$$\text{Length of swath} = \frac{1/2 \times 43{,}560 \text{ sq ft per acre}}{16}$$

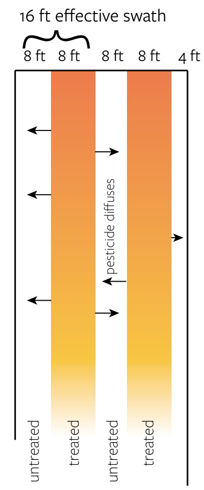
$$= 1{,}361 \text{ ft}$$

Step 3: Calculate the width of the plot

Plot width = number of 1/2 acre swaths × effective swath width

Plot width = 50 × 16 = 800 ft.





For boom applicators, swath width is considered to be the same as the boom length. Often, only alternate swaths are treated, making the effective swath twice the boom length because the pesticide diffuses into the untreated area. Determining the amount of pesticide needed for an application is simple. Just multiply the recommended rate per acre by the surface area of your treatment site.

Example:

How much herbicide is needed to treat an 8.1 acre lake at a rate of 120 lbs per acre?

Herbicide needed = treatment rate × acres to be treated

Herbicide needed = 120 × 8.1 = 972 lbs

Applications based on pesticide concentrations

Pesticide labels generally include tables that help you to determine the appropriate amount of pesticide formulation for a desired concentration and water depth. If a table is not provided, or the recommendation is given only as a surface acre application, you will need to calculate the amount of pesticide to use.

Pesticide concentration in water is usually referred to in ppm on a weight basis. Before determining the amount of herbicide to use for a particular application, you must first measure the surface area and water depth so that you can calculate water volume.

If the water depth is not uniform, it is important to determine the average depth. In small ponds, depth should be measured across the pond in at least 2 directions, taking sufficient measurements to adequately describe the pond's depth. The easiest way to calculate pond depth is to use a marked, weighted rope.

Make marks every 6 inches, and tie a weight to the end (this does not need to be fancy—a rock will work). Move across the water body in a straight line, and at intervals, drop the rope into the water and measure the depth of the water on the marked rope. The shorter the interval between measurements, the more measurements you will make, and the more accurate your average depth will be.

Once you have made these measurements, you can use the following formulas to calculate the average depth and then the volume in acre-feet:

$$\text{Average depth} = \frac{\text{sum of all measurements}}{\text{number of measurements}}$$

$$\text{Volume} = \text{average depth in ft} \times \text{surface area in acres}$$

Many recommendations state the application rate in amount of active ingredient (ai) or **acid equivalent** (ae) per acre.

Determine the pounds of ai you need with the following formula:

$$\text{lbs ai needed} = \text{ppm} \times \text{water volume (a.f.)} \times 2.7^{*}$$

Or rearrange the equation to find ppm from a given rate of application:

$$\text{ppm} = \frac{\text{lbs ai}}{\text{water volume} \times 2.7}$$

**In these equations, 2.7 is a constant. One (1) a.f. of water weighs 2,700,000 lbs, and therefore every 2.7 lbs of a substance in 1 a.f .of water is equivalent to 1 ppm.*

Finally, you must always convert rates to the amount of product when calculating how much herbicide you need. The following formulas will help you calculate the amount of product and active ingredient equivalents for dry and liquid formulations.

Dry formulations

To convert the commercial product and active ingredient in the formulation:

$$\text{Amount ai} = \text{amount product} \times \text{\% ai}$$

$$\text{Amount product} = \frac{\text{amount ai}}{\text{\% ai}}$$

Liquid formulations

To convert the commercial product and active ingredient in the formulation:

$$\text{lbs ai} = \text{gallons product} \times \text{lbs ai per gallon}$$

$$\text{Gallons product} = \frac{\text{lbs ai}}{\text{lbs ai per gallon}}$$

Determine how much product is needed to cover 16 acres for each of the different rates.

Example 1:

Needed: 6 lbs dry product per acre

$$\text{6 lbs of product per acre} \times \text{16 acres} = \text{96 lbs product}$$

Example 2:

Needed: 1 pound ai per acre of a 75% **wettable powder** (need to convert ai to product)

$$\frac{75\%}{100} = \text{0.75 lb ai per lb product}$$

$$\frac{\text{1 lb ai per acre}}{\text{0.75 lb ai per lb product}} = \text{1.33 lbs product per acre}$$

$$\text{1.33 lbs product per acre} \times \text{16 acres} = \text{21.33 lbs product}$$

Example 3:

Needed: 1 pint liquid product per acre

$$\text{1 pt per acre} \times \text{16 acres} = \text{16 pints or 2 gallons of product}$$

Example 4:

Needed: 1 lb ai per acre of a 4 lbs ai per gallon emulsifiable concentrate (need to convert ai to product)

$$\frac{\text{1 lb ai per acre}}{\text{4 lb ai per gallon}} = \text{0.25 gallons of product per acre}$$

$$\text{0.25 gallons per acre} \times \text{16 acres} = \text{4 gallons of product}$$

Example 5:

You need to treat a 1.6 acre pond with copper at a concentration of 0.5 ppm for algae control. How much copper sulfate will you need? The label tells you that $CuSO_4$ is 25% copper.

Step 1: Make measurements of the pond's depth and find the average depth.

You make 2 passes across the pond and make the following depth measurements: 2, 3, 4, 4, 6, 6, 4, 2 ft one way, and 2, 4, 6, 6, 6, 6, 6, 4, 2 ft the other way.

$$\text{Average depth} = \frac{\text{sum of all measurements}}{\text{number of measurements}}$$

$$\text{Average depth} = \frac{2+3+4+4+6+6+4+2+2+4+6+6+6+6+6+4+2}{18}$$

$$\text{Average depth} = 4.3 \text{ ft}$$

Step 2: Find the volume of the pond in acre-feet.

$$\text{Volume} = \text{average depth in ft} \times \text{surface area in acres}$$

$$\text{Volume} = 4.3 \times 1.6 = 6.88 \text{ a.f.}$$

Step 3: Determine the amount of copper to apply.

$$\text{lbs ai needed} = \text{ppm} \times \text{water volume in a.f.} \times 2.7$$

$$\text{lbs ai needed} = 0.5 \times 6.88 \times 2.7 = 9.29 \text{ lbs of elemental copper}$$

Step 4: Determine the amount of copper sulfate you will need.

$$\text{Amount product} = \frac{\text{amount ai}}{\text{\%ai}}$$

$$\text{Amount product} = \frac{9.29}{0.25}$$

$$\text{Amount product} \approx 37 \text{ lbs copper sulfate}$$

Percentage of parts-based applications

It is common for pesticide recommendation to be expressed as a given amount of product in a specific volume of water. Such recommendations are expressed as "**volume/volume**" recommendations or as a percentage of product in the spray solution. For example, a label may recommend using 1 gallon of pesticide formulation for every 20 gallons of spray mix.

Example 1:

A pesticide label recommends mixing 1 gallon of formulation to 20 gallons of final spray mix and **spraying vegetation to wet**. How much herbicide would be used with a 500 gallon tank?

$$\text{Herbicide per tank} = \frac{\text{volume of spray tank} \times \text{given herbicide amount}}{\text{spray mix amount given}}$$

$$\text{Herbicide per tank} = \frac{500 \times 1}{20}$$

$$\text{Herbicide per tank} = 25 \text{ gallons}$$

Example 2 — Volume/volume in water:

A 2% solution of glyphosate is recommended to control waterlilies. You have estimated that you will need 50 gallons of spray solution to treat patches of this weed. How much water and glyphosate do you mix together?

$$2\% \text{ of } 50 \text{ gallons is } 0.02 \times 50 = 1 \text{ gallon.}$$

To obtain the proper concentration, mix 1 gallon of glyphosate in 49 gallons of water for a total of 50 gallons of spray solution.

Granular applicator calibration

Calibrating granular application equipment requires you to measure the amount of granules spread over a known area. Calibrate using the pesticide granule to be applied or a similar blank, because each granule type flows differently. Recalibrate each time you switch the type or rate of granular pesticide.

Two variables affect the amount of granules applied per unit area:

1. size of the gate opening, and
2. speed of the applicator.

The rate at which granules flow out of the applicator depends on the size of the gate opening. A larger opening allows more granules to flow out, causing a higher delivery rate. Changing the size of the gate opening significantly increases or decreases the delivery rate.

The speed at which the granular applicator travels also affects total output per unit area. When travel speed increases, less material is applied per unit area, and when speed is reduced, more material is applied. When small changes to the delivery rate are necessary, adjust travel speed.

Adjust the gate opening or travel speed to fine-tune your application equipment. It may take many adjustments before the applicator is calibrated correctly.

Metered application for flowing water herbicide treatments

In order to treat flowing water, you must:

1. Determine the water flow rate in Cubic Feet per Second (cfs).
2. Determine herbicide application rate.
3. Determine the required exposure time for control.

You will need the following constants in order to do the required calculations:

- 128 oz per gallon, and
- 60 minutes per hour.

Example:

The product you are using requires 0.25 gallons/cfs/hour and requires 4 hours of exposure time. How much herbicide will be needed for this treatment, and what rate will it need to be applied at (in oz/minute).

Step 1. Determine the total amount of product needed for the treatment.

```
gal of product per treatment = application rate (in gal) × flow rate × exposure time

gal of product per treatment = 0.25 gallons/cfs/hour × 30 cfs × 4 hours = 30 gal
```

Step 2. Determine application rate in gal/minute.

$$\text{gal of product per minute} = \frac{\text{total gal of product per treatment}}{\text{exposure time in hours} \times 60 \text{ minutes}}$$

$$\text{gal of product per minute} = \frac{30 \text{ gal}}{4 \text{ hours} \times 60 \text{ minutes}}$$

$$= 0.125 \text{ gal/minute}$$

Step 3. Determine application rate in oz/minute.

```
oz/minute = application rate (gal/minute) × 128 oz/gal

oz/minute = 0.125 gal/minute × 128 oz/gal = 16 oz/minute
```

Calibration test

Conduct the calibration test over a measured area where the granules can be collected, such as a tarped area or driveway, or use a collection device mounted on the applicator. You may need to remove the applicator from your boat and attach it to a ground vehicle (truck, ATV) in order to do this properly. The catch container must not interfere with the chemical delivery. Use the following steps to calibrate a granular applicator.

1. Measure a known area. You can do this by measuring a swath width, measuring course length, and multiplying these measurements to get square feet, square acres, etc.
2. Set up a collection device: either an attachment or a tarp on the ground.
3. Apply at proper speed and gate setting.
4. Collect and weigh the amount of chemical "spread" over the measured area.
5. The delivery rate is the weight of material collected divided by the area covered.
6. Convert units to a pound per acre basis, or whatever basis the label states.
7. Adjust gate setting or speed to achieve the desired output.

Example:

To control submersed weeds in a pond, you choose to apply a granular formulation of an herbicide. The spreader covers a swath of 30 ft. At the set speed and gate openings, collect granules in a collection device while covering a 100-foot course. The collected material weighs 1.25 lbs. The label states an application rate of 20 lbs of product per acre (PPA).

$$\text{PPA} = 43{,}560 \text{ sq ft} \times \frac{\text{weight of collected material}}{\text{swath width} \times \text{course length}}$$

$$\text{PPA} = 43{,}560 \text{ sq ft} \times \frac{1.25 \text{ lbs}}{30 \text{ ft} \times 100 \text{ ft}}$$

$$\text{PPA} = 18.15 \text{ lbs}$$

18.15 PPA is less than 20 PPA. Increase the gate opening or decrease the travel speed and recalibrate to achieve the correct application rate of 20 PPA.

SPRAYER CALIBRATION

Proper sprayer function is essential for accurate sprayer calibration; therefore, follow the procedures outlined below before calibrating the equipment.

- Be sure sprayer nozzle tips are uniform and appropriate for the spray application to be made.
- Consult nozzle manufacturer's recommendations and the pesticide label.
- Thoroughly clean all nozzles, nozzle tips, and screens to ensure proper operation. Use a soft brush, never wire or any hard material. Add water to the spray tank and visually check nozzle output during sprayer operation. Discard and replace nozzle tips that produce distorted spray patterns.

- Check spray volume output of all nozzles and replace nozzle tips that differ by more than 5% of the average output of all nozzles, or replace all the nozzles if more than one is off.
- Check all pressure gauges. If a gauge is rusty or of questionable accuracy, replace it.

Sprayer output variables

The three variables that affect sprayer output are:

1. nozzle flow rate,
2. nozzle spacing or spray width, and
3. sprayer speed.

Nozzle flow rate varies with the pressure, the size of the nozzle tip, and certain characteristics of the spray solution. Increasing the pressure or using a nozzle tip with a larger orifice increases the output. Increasing pressure does not give a proportional increase in the output. For example, doubling the pressure does not double the flow rate; you must increase the pressure fourfold to double the flow rate. Therefore, adjust pressure for minor changes in spray delivery rate, not major ones. Operating pressure must be maintained within the recommended range for each nozzle type to obtain a uniform pattern and to minimize drift.

Effects of Sprayer Pressure on Delivery Rate (Speed Constant)	
Sprayer Pressure (PSI)	**Sprayer Delivery Rate (GPA)**
10	10.0
40	20.0
160	40.0

An easy way to make a large change in flow rate is to change the size of the nozzle tips. Depending on operating pressure, the speed of the sprayer, and the nozzle spacing, small changes in nozzle size can significantly change sprayer output per acre. Nozzle manufacturers' catalogs give information for selection of the proper tip size.

The surface tension, density, and **viscosity** (thickness) of the spray solution can affect the accuracy and uniformity of the application. Surface tension generally produces only small variations in flow. The flow rate through a nozzle decreases as the density increases. Oils are generally less dense than water, while fertilizers are more dense than water. An increase in viscosity will also cause a decrease in flow rate.

For boat sprayers, delivery rate is inversely proportional to the speed of the sprayer; that is, as speed increases, the amount of spray applied per unit area decreases at an equal rate. If spray pressure remains constant, doubling the sprayer's groundspeed will reduce the amount of spray per acre by half. For example, a sprayer applying 10 gallons per acre (GPA) at 12 miles per hour (MPH) would apply 20 GPA if the driver reduced speed to 6 MPH.

The width sprayed per nozzle also affects the spray application rate. The relationship is inverse, similar to speed and output. For example, if you are applying 20 GPA with flooding nozzles spaced 60 inches apart, switching to the same size nozzles spaced at 40 inches increases the application rate to 30 GPA.

Equipment Adjustments to Alter Delivery Rates	
To INCREASE GPA, Use:	**To DECREASE GPA, Use:**
Larger nozzles	Smaller nozzles
Slower sprayer speed	Faster sprayer speed
Increase pressure	Decrease pressure

Sprayer calibration determines the amount of spray volume the equipment delivers per unit area. Most labels direct the user to apply at a specific amount of herbicide per acre, but some label instructions include directions for an amount of herbicide to be applied per 1,000 square feet or some other area measure. Calibrate the sprayer and determine the delivery rate in the units used on the label, such as gallons per acre or per 1,000 square feet.

Once you have determined the size of the area to be treated and the desired concentration of pesticide, you must calibrate your equipment's output to ensure that the label rate of pesticide is being applied.

Maintaining an accurate application rate is difficult when applying aquatic pesticides because the equipment is mounted in a boat. Environmental factors such as wind velocity and speed, water flow, and vegetation density make it difficult to maintain a constant speed and perfect course. While the initial calibration of equipment for application of aquatic pesticides should be precise, the applicator's constant attention is necessary to make the application rate as constant as possible. Pesticides applied to water will mix within the treatment area, so precision becomes slightly less important. However, proper calibration and constant attention to the application are the most important part of any site treatment.

The following materials will be needed to calibrate aquatic pesticide application equipment:

- A watch—a stopwatch marked in tenths of a minute is useful.
- Calculator.
- Tape measure, or known length of your stride.
- 100-foot floating rope with a float tied to the end, for measurement.
- Buoys or poles.
- Scale with a capacity of at least 20 lbs.
- Blank herbicide granules.
- Enough 5-gallon buckets to measure water from each nozzle of your spray boom—at least one of these should be marked in pints or quarts.

Sprayers can be calibrated in various ways. Any way is acceptable as long as it provides accurate calibration and it is easy for you to do.

In most methods of calibration, you must determine the gallons per acre (GPA) of the spray solution for tank-mix equipment.

GPA can be determined with the following equations: For boom-type sprayers:

$$\text{GPA} = \frac{\text{gallons per minute (GPM)} \times 5{,}940}{\text{miles per hour (MPH)} \times \text{nozzle spacing in inches}}$$

For boomless sprayers:

$$\text{GPA} = \frac{\text{gallons per minute (GPM)} \times 495}{\text{swath width in feet}}$$

It may also be necessary to determine pesticide coverage in acres per minute (APM). Use the following equation:

$$\text{APM} = \frac{\text{swath width} \times \text{distance traveled} \times 60^{*}}{43{,}560 \times \text{time to cover distance}}$$

**Note: If a stopwatch that measures in tenths of a second is used, the component 60 in the numerator can be eliminated if the time to cover the distance is expressed in minutes instead of seconds.*

The easiest way to determine GPM for boom-type tank mix equipment follows:

1. Run the pump until all the air is out of the lines
2. Place a bucket under each nozzle of the boom and run the pump for one minute while catching the discharge
3. Measure the water in each bucket and add these quantities together, or pour them into one bucket and measure this quantity
4. If you have measured these quantities in ounces, divide by 128 (the number of ounces in a gallon)
5. To determine MPH:
   - Measure a distance of at least 200 feet (longer is better) and place a buoy at each end.
   - Drive over the course with the spray rig at the speed you feel comfortable with to do your spraying. If possible, do this in the water body you will be spraying.
   - Make at least 3 passes, timing each pass to the second. Average the 3 passes to get one number.
   - Put the distance you measured and the time in seconds into the following formula:

$$\text{MPH} = \frac{\text{distance in feet} \times \text{60 minutes per hour}}{\text{time in seconds} \times \text{88 ft per minute at 1 MPH}}$$

Example:

You have a 400 gallon tank. The boom is set up with nozzles 20 inches apart. You have collected an average of 92 oz from the nozzles. You traveled 400 feet in 45 seconds. How much herbicide would you add to the tank with the labeled rate of 2 quarts per acre?

1. Determine the MPH

$$\text{MPH} = \frac{\text{400 ft} \times \text{60 minutes per hour}}{\text{45 sec} \times \text{88 ft per minute}}$$

$$\text{MPH} = 6.1$$

2. Determine the GPM

$$GPM = \frac{92\ oz}{128\ oz}$$

$$GPM = 0.72$$

3. Plug this information into the formula

$$GPA = \frac{\text{gallons per minute (GPM)} \times 5{,}940}{\text{miles per hour (MPH)} \times \text{nozzle spacing in inches}}$$

$$GPA = \frac{0.72 \times 5{,}940}{6.1 \times 20}$$

$$GPA = 35.1$$

4. Divide the capacity of the tank by the GPA

$$\frac{400}{35.1}$$

$$= 11.4 \text{ acres}$$

At a rate of 2 quarts per acre, you need 11.4 × 2 or 22.8 quarts of chemical added to the tank.

Refill method

This method is probably the simplest of the many methods used to calibrate boom type sprayers.

1. Measure the effective spray width of the boom.
2. Divide the effective width of the boom into 43,560 (sq ft/acre) to determine the distance the sprayer must travel to cover an acre. Measure this distance on the water to be sprayed. Since the distance required to spray is usually quite large, the common practice is to reduce the course to a fraction of an acre, i.e.,1/10 or 1/16 of an acre.
3. Fill the spray tank and adjust the pressure (30–40 psi for most uses) and the equipment or applicator speed to the speed to be used on the site.
4. Fill the spray tank to a known reference line and spray the measured distance.
5. Measure carefully the amount of water required to refill the tank to the reference line. It is desirable to make 2–3 runs to obtain more accurate calibration. Returning the sprayer to exactly the same spot each time it is refilled will also increase accuracy.

Sprayer calibration results are valid only for the speed, nozzles, pressure, and spray width used during the calibration process. Significant changes in any one of these factors will require another calibration check. Calibrate your sprayer frequently each season, even if you do not change the system.

Example 1:

A sprayer with a 20-foot effective spray width is calibrated on 1/10 of an acre and requires 4 gallons of water to refill the tank after the calibration run.

$$= \frac{43{,}560 \text{ sq ft per acre}}{20 \text{ ft}}$$

$$= \frac{2{,}178 \text{ ft}}{10}$$

$$= 218$$

You must travel 218 ft to cover 1/10 of an acre.

4 gallons × 10 courses per acre = 40 GPA.

Example 2:

A sprayer has an 8-foot-swath. How many feet must you travel to cover one acre?

$$\text{Course length} = \frac{43{,}560 \text{ sq ft per acre}}{\text{swath width}}$$

$$= \frac{43{,}560}{8}$$

$$= 5{,}445 \text{ ft or over just 1 mile}$$

After spraying the 5,445-foot course, it takes 32 gallons to exactly refill the spray tank to the level prior to spraying the acre. This means the sprayer is delivery 32 gallons per acre.

Single nozzle method

This method of calibration is a quick and accurate way to calibrate any sprayer as long as the sprayer speed is known and can be accurately controlled. It requires checking only one nozzle on the sprayer, but assumes all nozzles are delivering the same amount. Check all nozzles before calibration to make sure that each nozzle is delivering within 5% of the average of all nozzles.

1. Set the pressure to the same level that will be used during the application and collect the water from one nozzle for one minute. Measure the water carefully.
2. Measure the coverage of a nozzle in inches. On a boom sprayer, the coverage is the same as the nozzle spacing.
3. Measure the swath of the boom.
4. Using conversion factors, determine the application rate.

Example:

A sprayer has 16 nozzles spaced 18 inches apart and the boom covers a 24 foot swath. When operated at 40 psi, one nozzle delivers 40 oz of water in 1 minute. The sprayer is to be operated at 4 MPH. What is the application rate?

Step 1: Determine gallons per minute

$$\text{GPM} = \frac{\text{40 oz per minute}}{\text{128 oz per gallon}}$$

$$= 0.313$$

Step 2: Determine acres per minute

$$18 \text{ in} \times \frac{4 \text{ miles}}{1 \text{ hour}} \times \frac{1 \text{ foot}}{12 \text{ inch}} \times \frac{1 \text{ acre}}{43{,}560 \text{ sq ft}} \times \frac{5280 \text{ ft}}{1 \text{ mile}} \times \frac{1 \text{ hour}}{60 \text{ min}}$$

$$18 \text{ in} \times \frac{4 \cancel{\text{miles}}}{1 \cancel{\text{hour}}} \times \frac{1 \cancel{\text{foot}}}{12 \cancel{\text{inch}}} \times \frac{1 \cancel{\text{acre}}}{43{,}560 \cancel{\text{sq ft}}} \times \frac{5280 \cancel{\text{ft}}}{1 \cancel{\text{mile}}} \times \frac{1 \cancel{\text{hour}}}{60 \cancel{\text{min}}}$$

$$18 \text{ in} \times 4 \times .0833 \times .0002296 \times 5280 \times .01667$$

$$= 0.01212$$

Step 3: Divide GPM by APM

$$= \frac{.313}{0.01212}$$

$$= 25.8 \text{ GPA}$$

Compressed air calibration (backpack & hand sprayers)

Most compressed air sprayers are small, hand-operated units carried by the operator; consequently, application factors such as speed, spray width, and pressure depend on who is spraying.

The following is just one of several possible methods used to calibrate hand-pressurized sprayers.

1. Measure and mark a square area 18.5 feet x 18.5 feet, or 342.25 square feet, which is 1/128 of an acre, preferably on a surface that will easily show the spray pattern width. An example would be a paved parking lot.
2. Starting with an empty liquid spray tank and using a container graduated in ounces, add 2 quarts (64 oz) of water to the spray tank.

3. Pressurize the sprayer and spray the area within the marked square. Maintain uniform operator walking speed, nozzle height, and tank pressurization.
4. 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.
5. Using a container marked in ounces, determine the number of ounces remaining in the sprayer.
6. Calculate 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 gallons per acre delivery of that sprayer.

Again, this method applies only to the operator who calibrated the sprayer.

Example:

You spray an 18.5 ft × 18.5 ft area. Your sprayer uses 36 oz to cover the marked area. Therefore, your sprayer is applying 36 GPA.

TANK MIXING

Mixing two or more chemicals together in the tank will often save time, save money, increase the number of pests controlled, and delay pest resistance. It is legal to tank mix chemicals if all products are labeled for the application site, but not if the label prohibits mixing specific pesticides.

You cannot tank mix if the combination of products exceeds the highest rate allowed by either pesticide label. For example, the highest labeled rate of "Weedgo" is 1.5 pints/acre (A). If you want to mix 1.5 pints/A "Weedgo" (which equals 0.38 lb ai/A of fluazifop) with 0.5 pints/A "Outtahere" (which equals 0.13 lb ai/A of fluazifop + 0.38 lb ai/A of fenoxaprop), the combination is illegal because it exceeds the highest rate of fluazifop, 0.38 lb ai/A. If both products were mixed at their highest allowable rate, the total amount of fluazifop would be 0.51 lb ai/A. This is greater than legally allowed. If instead you tank mixed 0.75 pints/A "Weedgo" (equals 0.19 lb ai/A of fluazifop) and 0.5 pints of "Outtahere" (equals 0.13 lb ai/A of fluazifop + 0.38 lb ai/A of fenoxaprop), the combination would be within the legal limit of fluazifop, 0.38 lb ai/A.

Illegal and Legal Applications of Fluazifop	
Illegal Application	
1.5 pints/A Weedgo + 0.5 pints/A Outtahere	0.38 lb ai/A of fluazifop + 0.13 lb ai/A of fluazifop
Total in tank mix	= 0.51 lb ai/A of fluazifop
This is OVER the legal limit of 0.38 lb ai/A	
Legal Application	
0.75 pints/A Weedgo + 0.5 pints/A Outtahere	0.19 lb ai/A of fluazifop + 0.13 lb ai/A of fluazifop
Total in Tank Mix	= 0.32 lb ai/A of fluazifop
This is WITHIN the legal limit of 0.38 lb ai/A	

Prior to tank mixing products, read the label and make sure tank mixing is not prohibited. Conduct a jar test for physical compatibility if the label does not specifically recommend the combination. Many labels give directions for a compatibility test. If it does not, mix the products with their carrier in a small jar at proper concentrations. Watch for changes and feel for heat, which indicates a reaction. If products do not mix properly, compatibility agents can solve the problem. Repeat the jar test with the compatibility agent. If everything looks fine, test the tank mix on a small portion of the site to make sure the combination is still effective and safe to the desirable vegetation before mixing hundreds of dollars' worth of solution.

Some products may be incompatible. Incompatibility results in gelatin or crystals forming in tank mix or pesticides losing their activity. In some cases tank mixes may increase injury to desirable plants. Many manufacturers recommend tank mixing their products with specific other products to increase the spectrum of pests controlled and to reduce development of resistant pest populations.

When labels include tank mix recommendations, the manufacturer has already conducted the compatibility and performance tests.

Tank mix pesticides in the following sequence to lessen incompatibility problems, unless otherwise directed by the label. Many labels give the proper pesticide mixing sequence.

1. First, partially fill the tank with water or other liquid carrier. Add buffers if necessary.
2. Dry materials go into the spray before liquid chemicals. If a wettable powder is used, put it in first as follows: Make a slurry with the wettable powder by adding a small amount of water to it until it has a gravy-like consistency. Slowly add this slurry to the tank with the spray tank agitator running.
3. Water-dispersible granules or dry flowables go in second. Flowables should be pre-mixed (1 part flowable to 1 part water) and poured slowly into the tank.
4. Liquid flowables should be added third. Liquids should also be pre-mixed (1 part chemical to 2 parts water) before blending into the tank.
5. Emulsifiable concentrates and adjuvants should be last.
6. Finally, add the remaining carrier to bring the spray mix to the full volume required for the job.

Adjuvants

Many pesticide products recommend adding adjuvants to the tank mix to increase product effectiveness. This recommendation is usually given as a percent concentration.

Example:

If you use an adjuvant at a 0.5 percent concentration by volume, how much should you add to a 300 gallon tank?

Amount of adjuvant = % concentration × tank volume

Amount of adjuvant = 0.005 × 300 = 1.5 gallons per 300 gallon tank

ADDITIONAL RESOURCES

More information on equipment and calibration can be obtained from the manufacturer or the dealer for each specific piece of spray equipment.

National Pesticide Information Center (NPIC). *Call and ask questions about pesticides and pesticide related topics*. Phone: 1-800-858-7378. http://npic.orst.edu/. Oregon State University, 333 Weniger Hall, Corvallis, OR 97331-6502.

The Pesticide Book, 6th edition. G.W. Ware and D. M. Whitacre. MeisterPro Information Resources: 2004. Information about pesticide chemistry, mechanisms, and modes of action.

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education. See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos. See page 2.*

FISH MANAGEMENT

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Understand how to monitor fish populations

B. Describe different methods of determining fish age

C. Define stunting and how to determine if a fish population is stunted

D. Describe different fish population management strategies

E. Understand the effects and properties of piscicides

F. Describe the factors that influence piscicide performance

G. Define neutralization

H. Describe different methods of piscicide application

I. Know how to calculate the amount of piscicide necessary for a given treatment

INTRODUCTION

This chapter is meant to provide you with a basic knowledge of how and when to apply fish management techniques, including piscicides. However, these activities should be performed only with the help and advice of a fisheries biologist. Not all details and site-specific decisions required for comprehensive and successful fish management are included here.

Monitoring fish populations

Fish are an extremely important part of any healthy aquatic ecosystem. Their activities provide important nutrients and biological controls for other animals; generally, they are the largest predator in a system.

However, fish can also be detrimental to pond and lake ecosystems, especially at very high population densities. Bottom feeding activities may cause water turbidity, and excessive wastes can negatively impact water chemistry, while some species outcompete native or desirable game species. All these impacts may detract from overall lake or pond quality, and may necessitate a fish management program.

Fish management is a continuous process that requires frequent monitoring in order to function effectively. Monitoring is generally conducted by capturing fish alive in some section of the lake or pond and extrapolating that data to describe the entire water body. This can be accomplished via several means:

1. hoop netting,
2. seining,
3. baited fyke netting,
4. trawling, or
5. trammel netting.

When fish are captured, their age, size, and species should be recorded along with their number, so that you can track changes in the health and species balance of the site.

Determining fish age

For most species, scales can be used to estimate fish age. During the colder parts of the year, scales grow more slowly, and leave behind a darker ring called an **annulus**, plural **annuli**, much like the bands of darker material in a tree stump. Counting these rings approximates the age of the fish.

Other methods of fish aging include sampling small bones called **otoliths**, or sampling fin rays. These methods are generally more accurate, but less accessible, than scale sampling. Otoliths are most useful in scale-less species like catfish or for fish with very small scales, such as lake trout.

Stunting is often a problem among sunfish; however, other species such as bullheads, perch, and crappie may also be prone to stunting. To determine if fish are stunted, scales are sampled to determine age and compared to length.

Stunting usually has 2 probable causes: either large predators are unavailable, or the fish are able to hide from the large predators in dense stands of weeds. Both causes allow the survival of large numbers of young fish that would normally be eaten by predators. Bass, which typically eat sunfish and others prone to stunting, are sight-hunters and have difficulty locating prey when large amounts of vegetation exist .

The stunted fish problem is a function of the **carrying capacity** of the lake or pond. A lake supports around 200–400 pounds of fish for every surface acre (this number may vary over the region served by this guide). This capacity can be utilized by thousands of sunfish that weigh only ounces each, or by a single 200-pound fish—unlikely, but possible. The more fish present, the smaller the proportion of total food supply available to each individual.

As with aquatic weed control, understanding the water body as an ecosystem is critical for proper fish management. A fish biologist can select the species most suited to a given water body, and can recommend physical alterations to improve conditions. Pond depth and surface area, water supply, quality, and temperature are parameters that should be determined when managing fish.

FISH POPULATION MANAGEMENT PRACTICES

There are many reasons to reduce the fish population in a water body. The system may have become contaminated with undesirable fish like carp, suckers, or bullheads. A trout pond may contain unwanted warm water fishes that are competing for food and reducing trout growth and survival. A lake may have suffered a winter-kill of only one type of fish, which has disrupted the predator-prey balance. As with all IPM practices, action thresholds should be set while monitoring the site, and multiple management methods should be used simultaneously for the best control. Non-chemical methods of control include:

- intensive angling,
- predator stocking,
- spawning bed destruction,
- cover reduction,
- water level drawdown,
- seining, and
- live trapping.

Intensive angling

Removal of unwanted fish species by angling can be an effective control, if the proper, species-specific baits are used and enough fish are removed to allow the recovery of other species. It is, however, a fairly labor-intensive and time-consuming method of control.

Predator stocking

Stocking predators such as northern pike, muskellunge, or walleye is often thought to result in sunfish control. Such attempts have been numerous but not very successful, probably because these fish prefer to eat things other than sunfish, and may result in more predation of bass than sunfish. Each northern pike or walleye requires the support of 5–10 acres of lake surface. These fish should never be stocked in small ponds or lakes, or really in any valuable water body.

Spawning bed destruction

Attempts have been made to control sunfish by destroying their eggs, either by raking or trampling their nests. For this tactic to be effective, however, almost every nest has to be destroyed, and since sunfish spawn over such a long period, hatch in so few days, and hatch so many young fish in each nest, control measures using this method are a long, arduous task that generally fails.

Cover reduction

When plant cover is abundant some fish (i.e., sunfish) can overpopulate a water body. Weeds can be reduced by physical, chemical, mechanical or biological means. This will leave scattered plant stands and promote predator fish.

Water level drawdown

Some fish populations can be controlled by manipulating the water level. Before drawing down, consider the impacts this will have on all other organisms in the pond or lake's ecosystem, particularly desirable fish and vegetation.

Total drawdown

This technique is used to eliminate all fish from a pond. Do not overlook fish in residual puddles. Spot applications of piscicides may help to attain total fish kill. Desirable fish like large bass can usually be salvaged and kept alive for restocking, if an area for holding them is available.

Partial drawdown

Lowering the water level is an effective means of concentrating fish, so that predators such as bass can feed more effectively. This tactic depends on having enough predators to consume a large portion of the unwanted fish. When the pond refills, survivors will hopefully be able to make more efficient use of the existing food supply, as long as overabundant aquatic plants have been controlled. Again, IPM programs involve the management of all components of a system; plants are as important in fish control as the fish themselves.

Predatory reduction of small fishes will be most effective if the partial drawdown takes place for a month or more in July or August, when temperatures are at their peak. You should carefully consider whether the danger of oxygen depletion and mass fish die-off will increase during partial drawdown.

Seining

Seining is often the most effective method of reducing unwanted fish populations; it works particularly well in small ponds, and its efficacy can be improved by seining in conjunction with water drawdown, in order to concentrate the fish, move water away from weed beds, and decrease the area and depth to be seined.

Seining is usually accomplished with a two-person team; each holds the end of a wooden upright that supports the end of the net. Floats along the top edge of the net keep the **seine** at the water surface, and weights on the bottom edge hold it to the pond bed.

For best results, the seine should be deeper than the deepest part of the pond, so that it can still function without being pulled away from the pond bed as it is drawn along. The seine must stay tight along the bed or the fish will escape underneath.

Seines can be built anywhere from 50–200 feet long, to fit large or small ponds. Small minnow seines 15–40 feet long can be used along shorelines to remove recently hatched fishes and fingerlings. Small seines are especially useful on recent hatches during spawning periods.

You should not rely on seining to give you accurate information about the fish populations in your site. Bass and carp, especially the older ones, are skilled at avoiding nets, so if you seine only small bass or carp, do not assume that larger fish are not present.

Live trapping

Fish traps are often useful for reducing populations in areas where obstacles to seining exist. Several different shapes can be constructed, and different shapes work better for different fish. One important component of a good trap is a pair of "wings" or extensions of the trap that guide fish toward the opening.

Traps should be placed in water that is just deep enough to cover them, either parallel or perpendicular to the shore, off peninsulas or in shallow bays where small fish gather. Support traps with poles or iron reinforcement rods driven into the bed. Up to 10 traps per acre may be needed.

Cylindrical-type fish trap[10]

FISH MANAGEMENT WITH PISCICIDES

The techniques discussed above can be effective for controlling unwanted fish species, but each method has its limitations. Piscicides have become important in fish management because they are able to overcome some of those limitations. However, pisciciding is a delicate operation that should only be undertaken with the help of a fisheries biologist or possibly your local extension specialist. In addition, your state or county may require a permit or certification.

Develop an acceptable plan for disposing of dead fish before making an application. You may be able to do this simply by digging a pit deep enough that raccoons and other animals cannot discover them. Burying will lessen the stench that goes along with decay. You may need approval from a government agency in order to dispose of fish waste in landfills, or may need to use a certain landfill. Fish composting is also a possibility, but again, regulations may apply. Check with your local extension office.

Piscicide properties and effects

Piscicides function by interfering with fish cellular respiration. They are usually not toxic to birds and large mammals; however, pigs may be adversely affected. In addition, piscicide concentrations lethal to fish will not harm submersed or emergent aquatic vegetation. However, the presence of aquatic plants can interfere with applications and reduce efficacy.

In **thermally stratified** lakes, some piscicides will not penetrate the **thermocline** (division between warm upper water layers and cold bottom layers). This can be advantageous if a management goal is to reduce warm-water species while retaining cold-water species. Still, stratification alone should not be relied upon to protect non-targets; some cold-water species forage in the upper waters, where they could be exposed to the chemicals. Similarly, warm-water species may move out of the upper waters and avoid the chemical.

Some piscicides leave a taste or odor in water that can remain for up to a month. This odor or taste can be removed by treating the water with activated charcoal.

Biologists have divided fish species into groups with high, moderate, and low sensitivity to piscicides. Generally, fish with scales are more susceptible than bullheads or other catfish; sunfish are moderately susceptible; perch and trout are highly susceptible. See "Table. Sensitivity to pesticides" on page 100.

FACTORS AFFECTING PISCICIDE PERFORMANCE

The most important factor in providing a lethal dose of piscicide to fish is the duration of exposure, i.e., contact time. In streams, chemicals can move past fish too quickly, and in standing bodies of water, rapid dilution or degradation is common. Fish must receive a lethal dose before the chemical moves out of the treatment area or is neutralized.

If the water body has outlets, it is important that the application method does not repel the fish; unless fish are contained in the treated area, they will exit the area and the application will be ineffective. Understand the properties of the product you select. One currently registered piscicide, rotenone, repels fish. If you use this compound, close off all outlets so that the fish cannot escape before receiving a lethal dose.

Excessive aquatic vegetation can interfere with piscicide dispersal. This problem can be avoided if piscicides are applied in the fall, after vegetation has died back. You should be aware, however, that piscicides may persist longer in the cool waters typical of spring and fall.

Turbidity can reduce effectiveness, just as it can for other pesticides, by adsorbing the chemical to organic materials in solution. **Silt**, too can, adsorb toxicants, reducing their effective concentration.

Registered piscicides

The U.S. EPA registers only two piscicides for fisheries use: rotenone and antimycin. A lamprecide is also registered for use. You should be familiar with the SDS for each product, and should follow all product label directions. As with any pesticide, use all safety equipment defined on the label when handling piscicides.

Rotenone

Rotenone is a naturally occuring substance derived from roots of certain tropical plants in the Legume (bean) family. Rotenone is the most used and most useful piscicide available for reclaiming lakes and ponds. It eliminates all fish, but after treatment the lake can be restocked with desirable species. It is relatively nontoxic to fish food organisms. It has a low persistence, and will not be toxic to fish that are stocked after a kill. Rotenone works by inhibiting respiration, so that fish cannot make the energy required to sustain bodily function within their cells. Rotenone treatments can cause water to have a bad odor and taste.

Antimycin

This compound is an antibiotic. Fish are not repelled by this compound, and thus it is useful for spot treatments in lakes. It is specific to fish, leaving other aquatic life unharmed, including waterfowl and mammals. In small concentrations, it is lethal to all stages of fish, from egg to adult. Like rotenone, antimycin is a respiration inhibitor. It is much more persistent than rotenone, and treated waters must be isolated for up to 7 days, until no evidence of toxicity remains.

Neutralization

You must plan for the containment and **neutralization** (pesticide degradation) strategies that accompany your treatment. Whenever possible, you must contain treated water until it is neutralized. If containment is not possible, the area required for neutralization should be accounted for in the treatment plan. Neutralization must be completed so that no fish are killed outside the target area.

A piscicide applied to water can be neutralized by natural degradation, dilution, or detoxification. The following factors determine the rate of neutralization in treated waters:

- volume of inflow to the treatment zone,
- tributaries,
- volume of outflow,

- temperature,
- turbidity,
- chemical and biochemical oxygen demand,
- species composition,
- water velocities across a stream channel, and
- dilution.

The toxic effects of piscicides can be almost immediately eliminated with **potassium permanganate** (**KMnO4**)**,** which is a strong oxidizing agent that has the ability to kill living organisms. KMnO4 is used to control fish diseases, reduce taste problems in fish, reduce **algal blooms**, and to detoxify piscicides. Care must be taken when using KMn**O4** because it can be toxic to fish; always follow label instructions.

Piscicide applicators may use $KMnO_4$ to set up borders in a lake to contain the piscicide. A cold or muddy water body will require more of this compound to neutralize a toxicant. This is because cold water will slow the rate of reaction, and muddy water contains organic particles that bind with the compound and make it less available.

While $KMnO_4$ can be used to detoxify water, it cannot remove the piscicide solvents and emulsifiers that allow the piscicide to mix with the water. These compounds can be removed with other chemical agents, or by a particular form of water purification called activated charcoal filtration.

Whenever handling or working with this product, use nose, throat, and eye protection. If the product is accidentally ingested, contact Poison Control immediately. Giving lemon juice, orange juice, milk, or a sugar solution can help reduce toxicity. If none of these are available, give large quantities of water.

When treating water bodies with an outlet and water control structure, like a valve or stoplogs, use the following precautions:

- Lower the water level as much as possible before treatment.
- Shut off the outflow as much as possible during treatment.
- Contain treated water within the project area until it has neutralized or detoxified.

If you are treating a water body with an outlet but no water control structure, you should:

- Determine containment or neutralization measures on an individual basis.
- Neutralize treated water before it leaves the project area.

Table. Sensitivity to pesticides		
Least susceptible	**Moderately susceptible**	**Most susceptible**
Black bullhead Bowfin Channel catfish Flathead catfish Shortnose gar White catfish Goldfish	Bibmouth buffalo Black crappie Bluegill Brook stickleback Common carp Fathead minnow Freshwater drum Largemouth bass Northern pike Northern redbelly dace Quillback Smallmouth bass Spotted sucker Sunfish White crappie White sucker	Gizzard shad Minnows Trout Walleye Yellow perch

METHODS OF APPLICATION

It is essential that the fish toxicant you are using be distributed evenly throughout the water body. Depending on the specifics of your site, various methods can be used.

Backpack sprayers are useful for treating small ponds. They can also be used to cover marshy areas and shorelines with thick vegetation.

Failure to cover these areas adequately may cause the entire project to fail.

Motor-driven boats are used for larger ponds and lakes. Spraying is usually done with a centrifugal pump with enough pressure to create a stream of water 30–40 feet long. The piscicide should be diluted according to the manufacturer's directions before spraying it on the water, in order to prevent waste and excessive application of the chemical.

Dilution is accomplished with a minor modification to the pump system:

- Connect the pump intake to a 45-degree **wye** (Y-shaped connector).
- Connect one arm of the wye to the reservoir filled with product in the boat.
- Connect the other arm to a hose that draws diluting water from the lake.
- Adjust valves on the 2 lines to adjust the proportion of water and piscicide.

A **venturi rig** is used for deep-water treatments in large lakes. It is very effective at dispersing the chemical through the water column. This rig is constructed by attaching a boat bailer to the lower unit of the outboard motor. The bailer is connected by a length of hose to a large graduated tank in the boat. Chemical is siphoned from the tank at an even rate if the boat speed is constant. A valve attached between the hose and the tank regulates the dispersal of the chemical.

Chemicals can be released into water below the thermocline by attaching a heavy metal pipe or weights to the discharge hose, as described in the section on pesticide application techniques. A weight up to 30 pounds may be needed, even at slow running speeds. Check the depth of the pipe by driving toward shore until the pipe strikes bottom, and measure the depth at this point.

To distribute a piscicide over the surface of a large lake, subdivide the lake into sections and apply a proportional quantity of chemical to each section. You may mark the sections with shore markers and buoys. Because the quantity of chemical must be proportional to the volume of water to be treated, you may need to run the venturi rig across deeper sections more than once.

For small lakes, a venturi rig application will be most efficient when done in a spiral pattern. Start from shore and proceed toward the center in a spiral pattern. The distance between successive whorls should not exceed 30 feet, for correct coverage, since wind and wave action may not carry the chemical to all water areas equally.

Flowing waters

Because flowing waters are very complex systems, applications to streams, irrigation ditches, or other flowing water require careful planning. Flowing waters may require continuous introduction of products from one or more stations for an extended period of time. Effective treatment of flowing water systems depends on several factors:

- *chemical concentration*—the volume of the area to be treated must be calculated
- *contact time*—flow rate in cubic feet per second must be determined, and
- target species

Applications to flowing water require special considerations:

- water temperature—colder waters may reduce efficacy,

- water turbidity and pH, and
- weather conditions.

Piscicide calculations

You should be able to work through the following examples to familiarize yourself with piscicide application methods and calculations. Before making any application, you must

1. Identify the species to be controlled.
2. Obtain all necessary permits and certifications.

Standing water

For a standing water application, you must determine the following parameters:

1. recommended label rate,
2. effective contact time (ECT), determined by species susceptibility, and
3. volume of water to be treated.

Example:

You are treating a pond that is 100 ft by 75 ft by 4 ft average depth with antimycin to eliminate stunted sunfish. The recommended label rate is 3 ppm, and the ECT for this species is 10 minutes. You are using a sprayer with an output of 0.22 gallons per minute (GPM).

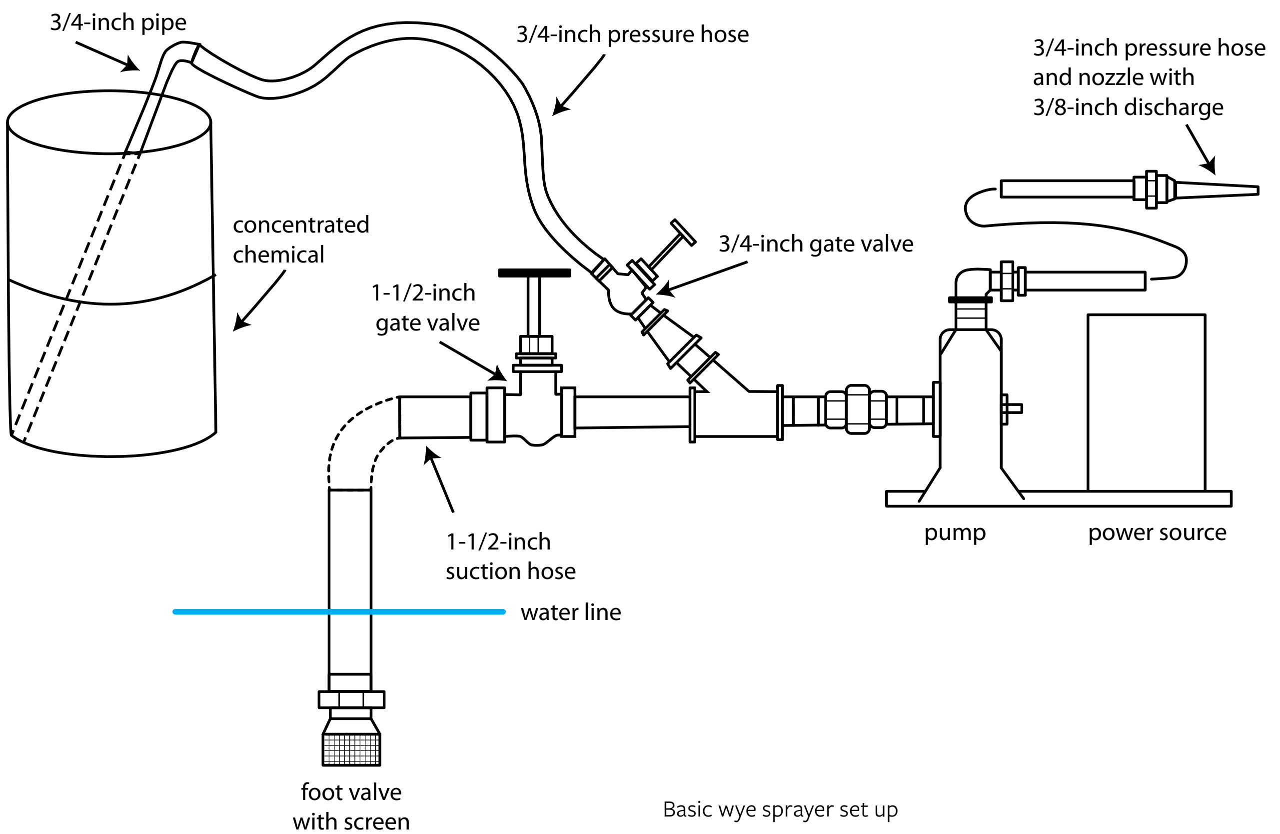
1. Determine the volume of the pond in a.f.:

$$\text{Volume} = \frac{l \times w \times d}{43{,}560 \text{ cubic ft per a.f.}}$$

$$= \frac{100 \times 75 \times 4}{43{,}560}$$

$$= 0.689 \text{ a.f.}$$

2. Determine the gallons of piscicide needed for a 3 ppm application:



Basic wye sprayer set up

```
Conversion factor   =   0.326 gallons of piscicide per a.f. per ppm
```

$$\text{Gallons of piscide} = \frac{\text{a.f. to be treated} \times 0.326\ \text{gallons}}{\text{a.f. per ppm} \times \text{desired ppm}}$$

$$\text{Gallons of piscide} = \frac{0.689 \times 0.326\ \text{gallons}}{\text{a.f. per ppm} \times 3\ \text{ppm}}$$

$$= 0.674\ \text{gallons}$$

3. Convert gallons to mL:

```
Milliliters     =   gallons × 3,785 mL per gallon
Milliliters     =   0.674 × 3,785 mL per gallon
                ≈   2,551 mL
```

4. Determine the output of the spray tank over the 10 minute application:

```
Sprayer output  =   Duration of treatment (ECT) × Application rate GPM)
Sprayer output  =   10 minutes × 0.22 GPM
                =   2.2 gallons
```

5. Convert gallons to milliliters:

```
Milliliters     =   gallons × 3,785 mL per gallon
Milliliters     =   2.2 × 3,785 mL per gallon
                =   8,327 mL of solution
```

6. Determine the amount of carrier to be added to the tank:

```
mL water        =   mL total solution – mL piscicide
mL water        =   8,327 mL – 2,551 mL
                =   5,776 mL water
```

You can now fill your tank properly.

Potassium Permanganate ($KMnO_4$)

If you need to apply $KMnO_4$ to neutralize the piscicide, work through the following example. You will need to use the following conversion factors:

1. 29.573 mL per oz
2. 16 oz per lb
3. grams are equal to mL

Example:

You are applying KMnO4 to neutralize the piscicide you added in the standing water example (2,551 mL). How much of the neutralizer will you need?

1. Determine clarity and water temperature values:

Clarity Values		Water Temperature Values	
Clear	1.00	Hot (>30°C)	1.00
Turbid	1.25	Warm (24°–29°)	1.25
Muddy	1.50	Cold (18°23°)	1.50

2. Determine the multiplier value if you are applying the neutralizer to hot, turbid water.

Multiplier value = clarity value + water temp value

Multiplier value = 1.25 + 1.00

= 2.25

3. Determine the lbs of $KMnO_4$ needed:

Grams of $KMnO_4$ = oz piscicide × multiplier value

Convert milliliters to ounces:

Ounces $= \dfrac{2551 \text{ mL}}{29.573 \text{ mL per oz}}$

= 86.26 oz

Grams of $KMnO_4$ = 86.26 × 2.25

= 194 oz

Convert oz to lbs:

lbs $= \dfrac{194 \text{ oz}}{16 \text{ oz per lb}}$

= 12.13 lbs of $KMnO_4$

Marker Dye

You may use a marker dye to determine where the piscicide has been added in flowing water. Spray the dye before piscicide application. It will enable you to know where to apply the detoxicant, if any is needed. Follow the manufacturer's directions.

Flowing Water

In order to treat flowing water, you must:

1. Determine the stream's flow rate. See the previous chapter for techniques on how to estimate this rate.
2. Set barrier nets above and below the treatment section and mixing section of the stream being treated.

You will need the following constants in order to do the required calculations:

- 1.7 mL per minute per cfs per ppm of piscicide product
- 3,785 mL per gallon

Example:

Determine the amount of piscicide and solution needed to treat a flowing stream. The product you are using recommends a rate of 4 ppm for an ECT of 10 minutes. The stream's flow rate is 26.5 cfs, and you are using a sprayer with an output of 0.22 GPM.

1. Determine the milliliters of product per minute:

```
mL of product per minute  =  flow rate(in cfs) × 1.7 × application rate
mL of product per minute  =  26.5 cfs × 1.7 × 4 ppm
                          =  180 mL per minute
```

2. Determine the total volume of product for the ECT:

```
Total mL product          =  mL product per minute × ECT
Total mL product          =  180 mL per minute × 10 minutes
                          =  1800 mL
```

3. Determine the output of the sprayer over the ECT:

```
Sprayer output            =  ECT × application rate (GPM)
Sprayer output            =  10 minutes × 0.22 GPM
                          =  2.2 gallons of solution
```

4. Convert gallons to milliliters:

```
Milliliters        =   gallons × 3,785 mL per gallon
Milliliters        =   2.2 × 3,785 mL
                   = 8,327 mL solution
```

5. Determine the amount of carrier to add:

```
mL water           =   mL total solution – mL piscicide
mL water           =   8,327 – 1800
                   =   6,527 mL water
```

ADDITIONAL RESOURCES

United States Fish and Wildlife Service: www.fws.gov. Aquatic Invasive Species Regional Coordinator for Region 6: Erin Williams: 303-236-4515, erin_williams@fws.gov.

USFWS Sea Lamprey Unit: U.S. Fish and Wildlife Service Marquette Biological Station. 3090 Wright Street, Marquette, MI 49855-9649. Phone: 906-226-6571. https://www.fws.gov/midwest/marquette/.

Freshwater Fisheries Management. Robin G. Templeton, 1995. Oxford: Fishing News Books.

American Fisheries Society. https://fisheries.org/. *A nonprofit organization formed to improve the conservation and sustainability of fishery resources and aquatic ecosystems by advancing fisheries and aquatic science and promoting the development of fisheries professionals. Online library of journals and books, network of professionals.*

Bender, R.F., S.J. Moeller and S.S. Foster. 1998. *Composting mortality: An environmentally friendly dead animal disposal option*. In: Proceedings of Animal Production Systems And The Environment. Des Moines, Iowa.

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education. See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos. See page 2.*

AQUATIC INVERTEBRATE PESTS

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Define invertebrate

B. Know the different types of aquatic invertebrates

C. Define mollusk

D. Understand the problems associated with large mollusk populations

E. Describe the life cycle of the zebra mussel

F. Describe the methods of zebra and quagga mussel control

G. Understand the differences between oxidizing and non-oxidizing molluscicides

INTRODUCTION

Invertebrates are animals without a spine. They are important links in aquatic food chains. Typical aquatic invertebrates include:

- worms,
- **leeches,**
- water fleas,
- insect **larvae,**
- snails, and
- mussels.

You should be familiar with the invertebrates that are considered undesirable in aquatic systems, and the impact of herbicide treatments on invertebrates.

MOLLUSKS

Mollusks are invertebrates with soft, unsegmented bodies, which are usually enclosed in shells. Snails and mussels, also known as freshwater clams, are included in this group.

Snails

Snails and some aquatic birds are carriers of a tiny, free-swimming worm larva of the genus *Schistosoma*, which burrows into and irritates human skin; the symptoms are referred to as **swimmer's itch**, or **schistosomiasis**. This phenomenon is fairly uncommon in our region.

Most snails do not carry the parasite; the mere presence of snails is not sufficient to justify treatment or control. You should be sure that the snails present are the larva's host before making management treatments. The best way to control snails is to remove their habitat: algae, plants, and benthic debris.

Snails[11]

If birds infected with *Schistosoma* are discovered, they are vaccinated with a specific drug treatment to prevent the parasite's spread into other waters.

Mussels

Mussels are a group of bivalves (creatures with two shells). The two halves, or valves, of the shell are joined by a strong ligament. They have a large organ called a foot, which they use to push or pull themselves across the substrate. Marine mussels and some freshwater mussels like the zebra mussel (*Dreissena polymorpha*) and quagga mussel (*Dreissena rostriformis bugensis*) produce ligaments called **byssus threads** that secure the mussel to its substrate.

Zebra mussels[12]

Mussels feed by filtering water through an internal siphon; the plankton and other microscopic organisms caught in the filter become the animal's food.

One mature female zebra mussel can produce up to 40,000 eggs per season; colonization of a water body can occur rapidly. Fertilization occurs outside the body, and the resulting microscopic larvae, called veligers, float freely in the water column for 8–14 days. They can be carried great distances by water currents, but must attach to a firm surface within a month or they will die. Zebra mussels attach to most substrates including sand, silt, and harder substrates.

Those that can attach and survive will become double-shelled mussels with light and dark banding within three weeks, and will become mature within a year. Most zebra mussels are thumbnail-sized, but can reach two inches long. They live an average of three and a half years, but many live as long as five years.

Ecological and biological issues

The zebra mussel's feeding habits can greatly damage the food chain of water systems. Each adult mussel can filter about 1 liter of water per day, and nearly all the particulate matter in that liter is strained out of the water. This can lead to increased water clarity (up to a doubling of the Secchi depth), which can in turn lead to deeper light penetration and increased growth of aquatic plants. In addition, water temperature may rise and thermocline depth can increase. Instead of passing their uneaten plankton back into the water, mussels bind it with mucous into a pellet called **pseudofeces**. These pellets are ejected from the mussel's siphons, and accumulate within the mussel colonies.

A considerable quantity of plankton and other nutrients are removed from the water system through this process, becoming unavailable to the plankton-feeding forage fish that support larger sport and commercial fishes.

In addition to removing nutrients, mussels can become incredibly prolific on reefs, shorelines, and other rocky habitats. They attach to a hard surface, and then to each other, sometimes forming layers several inches thick. The accumulation of pseudofeces in these colonies creates a foul environment: as the waste particles decompose, dissolved oxygen is depleted and water pH drops. This may have effects on fish, vegetation, and other large organisms.

In general, waters invaded by these mussels show a decline in biodiversity, which can affect the stability and resilience of the water system; again, healthier ecosystems tend to have high numbers of species with few individuals from each.

Impact on water supply and recreation

In addition to causing ecological and habitat damage, zebra mussels can have great impacts on recreational and municipal water uses. They encrust and clog municipal and industrial water intake pipes, thereby reducing pumping capabilities. When they die and decompose, their bodies cause bad taste and odor in drinking water. And, though a zebra mussel may die, its shell stays firmly attached to its substrate.

Zebra mussels can accumulate in water intakes of both inboard and outboard motors, grow inside motors and cause engines to overheat. Navigational buoys can become encrusted with mussels and sink out of sight due to the extra weight. Dock pilings can be structurally damaged by large infestations, and continued attachment can even cause corrosion of steel and concrete. Beaches are less attractive when sharp mussel shells wash ashore.

Mussel management

There are many methods of mussel control. A combination of these techniques is more likely to produce results than using any single method. The control of zebra mussels is very difficult and will require years of treatment.

Prevention

Prevention is the most important method of management, especially with mussels; as soon as they are present, they are very hard to eradicate.

One component of prevention is education. Boaters and other recreational water users must understand the threat presented by non-native mussels. A cooperative effort between boat owners, pest managers, and state agencies is necessary to arrest the spread of these species. Use the "Drain, Clean, and Dry" process described on page 7 to minimize this risk.

Other preventative methods include using filters and screens on intake pipes and other water conveyance systems, using coatings to prevent attachment, or using specific materials in waterway construction.

Coatings made of copper or zinc are toxic to zebra mussels and will prevent attachment. Silicon-based coatings are non-toxic and make attachment physically difficult. Pipes made of copper, brass, or galvanized metal are toxic to mussels and will prevent attachment.

Another option is **ultraviolet light** (**UV**) **treatment**: A filtration system is constructed around an inflow pipe. As the water flows past an internal lamp, a specified dose of UV radiation alters the essential functions of zebra mussel veligers and prevents their attachment to intake surfaces.

Physical control methods

These methods attempt to control mussels by physically removing them from the substrate. Because mussels are so tenacious, these techniques may require a great deal of manual labor. If the mussels fall off their substrate, they should be removed from the body of water and disposed.

- Electrical shock and sonic vibrations.
- **Pigging**: this is a process to remove mussels from infested water lines. It involves pushing flexible plugs, often called pigs, through the line with high pressure, hopefully tearing the mussels off the substrate.
- High pressure wash.
- Wire brushes.

Cultural control methods

These methods involve manipulating the mussels' habitat to kill or remove them. These are generally effective, but may have environmental consequences for other species.

- **Dewatering** or **desiccation**: This can be done by lowering the water level until the mussels dry out and die. However, their shells are left behind and must still be removed.
- Steam injection: Mussels do not survive in water temperatures higher than 32°C. Exposure to 34° water for 420 minutes will yield 100 percent mortality. If the water can be heated, this is an effective control and has minimal environmental impact.
- CO_2 injection: This process lowers the water pH below the level that mussels can tolerate; however, it may have detrimental effects on other organisms in the area.

Biological control

Predators, parasites, and pathogens may be effective against mussels. These natural enemies may be augmented with certain management practices or by releasing more of them into the water.

Bacillus alvei, *B. brevis*, *B. circulans*, and *B. laterosporus* bacteria have been found to be effective against several zebra mussel life stages. These bacteria were also effective against *Biomphalaria glabrata*, the snail vector of schistosomiasis.

Chemical control

Several chemicals are available and registered as molluscicides to control zebra mussels. Waters must comply with environmental regulations for safe discharge; therefore, it is most suitable for problems in closed systems or internal piping.

Chemical control options can be categorized as either oxidizing or **non-oxidizing**. These categories are determined based on the compounds chemistry and affect how each type affects mussels.

Oxidizing compounds have similar modes of action which lead to toxic and lethal effects. They are most useful as preventive treatments, and should be added to a water body or system throughout the breeding season. Continuous applications for 2–4 weeks can eliminate established adult colonies, depending on conditions.

Zebra mussels have sensitive **chemoreceptors** that alert them to certain toxins in their environment. Mussels do can detect oxidants, and will close their shells for up to 2 weeks, reducing the treatment's efficacy. The concentration and contact time required for each chemical will vary depending on temperature, water chemistry, and the physiology of the mussel at that point in time.

Oxidizing compounds are summarized in the following table:

Oxidizing Molluscicides	
Name	**Chemical Symbol**
Bromine	Br
Chlorine	Cl
Chlorine gas	Cl_2
Liquid sodium hypochlorite	NaClO
Powdered calcium hypochlorite	$Ca(ClO)_2$
Chlorine dioxide	ClO_2
Chloramines (monochloramine)	NH_2Cl
Hydrogen peroxide	H_eO_e
Ozone	O_3
Permanganates	$-MnO_4$
Potassium permanganate	$KMnO_4$
Calcium permanganate	$Ca(MnO_4)_2$

Non-oxidizing molluscicides were developed for disinfection and algae control. They often have a higher per-volume cost than oxidizing molluscicides, but may end up being just as cost-effective due to lower use rates and shorter exposure requirements. Most are easy to use and will not cause corrosion in metal components. Treatment is generally done intermittently rather than as a continuous application, with three applications per year: in the early season, during peak veliger activity, and when evidence of settlement is first seen.

In addition, most of these products will naturally degrade. Some, however, may require detoxification or deactivation to meet state and federal discharge requirements. In general, these compounds will not form toxic by-products.

The following table summarizes non-oxidizing molluscicides.

Non-oxidizing Molluscicides	
Name	**Chemical Symbol / Example**
Aromatic hydrocarbons	Benzene and its derivatives
Endothall	
Metals and metal salts	
Copper ions	Cu^+, Cu2+
Potassium	K^+
Potash	K_2O
Potassium chloride	KCl
Quaternary ammonium compounds	Benzethonium chloride

The timing of molluscicide treatment is important and will differ depending on the type of pest problem that exists. Several different treatment timing strategies are described below.

1. **End of season treatment**: This strategy targets adult mussels. The chemical is applied for a period sufficient to kill all adults established in the water body at the end of the breeding season. Provides an 80–90% mortality rate.
2. **Periodic treatment**: Targets adult mussels on a regular basis; usually used when density and size of adults remains fairly low.
3. **Continuous pulse treatment**: Low levels of chemicals are used to target veligers to prevent infestation. Because veligers are more susceptible than adults, lower concentrations can be used.
4. **Continuous treatment**: Discourages all veliger settling. This technique is usually used where any plugging or fouling would be extremely detrimental.

Leeches

These invertebrates are generally not an issue in the Western states. Very few leech species attach themselves to humans or mammals; therefore, it is important to know whether the leech species you observe is causing a problem and whether it can be considered a pest.

Leech habitats include accumulations of leaves, twigs, or other detritus at the lake bottom. Most leeches will be eaten by large bluegills and bass. Reducing the amount of organic debris and preventing or controlling beds of dense vegetation will also help reduce leech populations.

Leech[13]

INSECT PESTS

Insects, class Insecta, are invertebrates in the phylum Arthropoda that have an exoskeleton, which is an external supportive covering consisting of three body segments, three pairs of legs, and two antennae. Other classes within Arthropoda include arachnids and crustaceans. Only two aquatic insects are generally considered pests: **black flies** and mosquitoes.

Black flies

Black flies are true flies in the order Diptera. Their larvae live in clean, fast-flowing streams and rivers. Adults emerge in great numbers from these water bodies in the spring and continue through the summer, though black fly adults are usually most abundant in May and June. Female black flies bite and suck blood.

A common method of black fly control is to apply a larvicide to the water where larvae are found. The bacterium-derived larvicide ***Bacillus thuringiensis*** (***Bt***) is available in liquid form and is very specific, affecting only black fly and mosquito larvae, not other aquatic organisms.

Mosquitoes

In order to manage mosquitoes commercially and with pesticides, you must become registered either in a mosquito control category or a public health category. The category numbers for each state are listed below:

State	Category
Colorado	110
Montana	38
North Dakota	Public Health Pest Control
South Dakota	9
Utah	8
Wyoming	908 and 911-O

Non-chemical controls of mosquito populations include:

- eliminating sources of stagnant water, such as bird baths, tires, pet dishes, buckets, open boats, etc.,
- increasing water movement in permanent water features,
- reducing shallow water when feasible, and
- reducing the density of aquatic plants.

ADDITIONAL RESOURCES

Army Corps of Engineers Zebra Mussel Information System. Available at http://www.erdc.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/476783/invasive-species- information-system/. *An interactive system designed to allow easy access to a wide variety of information on zebra mussels, including identification, life history, impact, monitoring and detection, management strategies, contaminant issues, as well as an extensive bibliography.*

Practical Manual for Zebra Mussel Monitoring and Control. R. Claudi and G.L. Mackie, 1994. *Biology, monitoring, structures of concern, chemical and nonchemical controls, case histories.*

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education.* *See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos.* *See page 2.*

AQUATIC VERTEBRATE PESTS

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Define the term "vertebrate"

B. Describe different vertebrate pests

C. Understand the problems associated with each pest

D. Describe different methods of vertebrate control

INTRODUCTION

Vertebrates are animals that have a backbone or spinal column (vertebrae). Birds, reptiles, amphibians, fish, and mammals, including bats, are all vertebrates.

Most wild mammals, birds, reptiles, and amphibians are beneficial and important parts of an aquatic ecosystem. However, some may conflict with your management goals for the water body, including the concerns of residents around the water body and aquaculture businesses. In addition, some animals are vectors of disease organisms. They can serve as disease reservoirs for several diseases, including rabies, hantavirus, rocky mountain spotted fever, bubonic plague, leptospirosis, histoplasmosis, and salmonellosis.

If you need help with a sick or injured animal or one that may be suffering from pesticide poisoning, you can ask for help from the National Wildlife Rehabilitators Association (NWRA).

The International Wildlife Rehabilitation Council (IWRC) may also be able to provide assistance with an injured or sick animal.

If you do not know how to manage an animal problem, ASK.

MUSKRATS AND MARMOTS

These rodents dig burrows that may weaken stream banks and cause cave-ins, and can weaken dams and cause leaks. They prefer to dig in steep banks. **Muskrats** typically burrow beneath the pond surface.

Keeping earthen dams mowed will reduce cover that marmots and muskrats find harborage in. Removing cattails, arrowheads, and other emergent plants will deprive muskrats of food and cover. Armoring the shore with rocks or cement chunks will discourage burrowing.

Controlling muskrat and marmot populations is feasible only if the water body is far from other habitat for these animals. If it is near other waterways or wetlands, these animals will eventually move in. In this case, it may be better to control the damage by reinforcing the embankments rather than trying to control the animals.

Yellow-bellied marmot (*Marmota flaviventris*)[14]

Canadian goose. When present in high numbers, geese may be considered pests[15]

BIRDS

Ducks, geese, and other birds can be carriers of diseases, and they can also significantly increase bacterial populations and add nutrients to the lake or pond. Several kinds of fish-eating birds may reduce fish populations in ponds, including the following notable predators:

- herons,
- kingfishers,
- mergansers, and
- domestic Muscovy ducks.

All of these species can be scared away with noise-making devices. Scarecrows, rubber snakes, and owl or hawk decoys can also be effective. Decoys should be positioned imaginatively and moved often.

You can discourage herons by deepening the edges of ponds to form steep underwater slopes. Kingfishers are discouraged by removing all perches, like posts and dead tree limbs, that are close to the pond. Muscovy ducks should be confined to a small part of the pond.

Other nuisance species include:

- geese,
- gulls, and
- some ducks.

These species can be detrimental by feeding on lawns and depositing considerable amounts of feces. String or bird repellent tape can be strung to discourage the geese and ducks from entering a certain area. The string you use must be strong.

Several types of bird repellent tape are available; usually, it is brightly colored and coated with mylar. The tape's physical presence, flashing colors, and noisiness make it an effective tool for managing bird populations in certain situations. Repair the tape regularly.

Large tethered helium-filled balloons can be effective in repelling blackbirds, ducks, geese, gulls, and sandhill cranes. The balloons must be moved regularly so that the birds do not become acclimated to them.

Geese are very intelligent animals and will often be able to find a way around any control efforts you may make. Alternating methods can help control geese over longer periods of time.

Harassing birds excessively may be a violation of the Migratory Bird Act. Contact a local wildlife biologist or the U.S. Fish and Wildlife Service to learn more about this law and your responsibilities under it. Shooting certain birds without a license or shooting out of season can lead to criminal prosecution.

SNAKES

Snakes are beneficial animals that are very unlikely to cause harm to humans. However, some people consider the presence of snakes a nuisance, either because of fear or aesthetics. Fish-eating water snakes may take up residence near a pond or lake, especially when a stream is nearby. These snakes usually pose problems only for trout and minnows.

Mowing pond bank vegetation, removing logs, tree roots, branches, and large stones from around the shoreline will reduce water snake habitat. However, mowing may reduce the advantage of having a vegetation buffer strip to filter nutrients and silt out of runoff water.

BEAVERS

Beavers are very well adapted to aquatic environments and may be found anywhere there is a year-round source of water. Most damage caused by beavers is a result of dam building or tree cutting.

A single tree or shrub can be protected, if necessary, from beaver damage by encircling it with securely fastened wire mesh. Stucco wire or other stiff products are preferable; common chicken wire, unless well-staked, is usually too light to do the job. The fencing should be a least 30 inches high.

Where beavers are causing significant damage, the most effective management technique is live trapping. Check with your department of wildlife for permit requirements or seasonal trapping restrictions. Check with the landowner before relocating a beaver on their property.

Beaver in Grand Teton National Park, Wyoming[16]

ADDITIONAL RESOURCES

Colorado Commercial Application and Safety Training Guide: Outdoor Vertebrate. Available from the Colorado State University Resource Center at www.csuextstore.com/store/pc/home.asp, Phone: 970-491-6198 or toll free 877-692-9358, Fax: (970) 491-2961. 115 General Services Building, Colorado State University, Fort Collins, CO 80523.

National Wildlife Rehabilitators' Association: 2625 Clearwater Rd, Suite 110, St. Cloud, Minnesota 56301. Phone: 320-230-9920. https://www.nwrawildlife.org/default.aspx. *This organization can help you find a wildlife rehabilitator in your area. The NWRA is an organization of individuals committed to the treatment and temporary care of injured, diseased and displaced indigenous wildlife and the subsequent return of healthy animals to appropriate habitats in the wild. Members of the NWRA meet minimum standards and go through an accreditation program in wildlife rehabilitation.*

International Wildlife Rehabilitation Council: PO Box 3197, Eugene, OR 97403. Phone: 408-271-2685. www.iwrc-online.org. *The IWRC's mission is to preserve and protect wildlife and habitat through wildlife rehabilitation.*

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education.* *See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos.* *See page 2.*

AQUATIC PEST PROFILES

LEARNING OBJECTIVES

After reviewing this chapter, you should be able to:

A. Know the description, habitat and distribution, biology and ecology, and IPM methods for the aquatic pests listed in this chapter

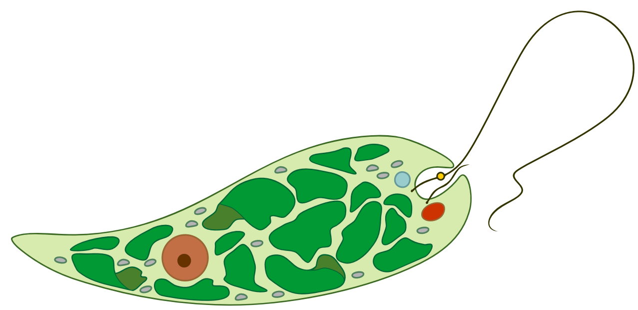
INTRODUCTION

This chapter is meant to help you determine what pest you may be working with: how to recognize it, its importance in the law and in the environment, and how to control it if it becomes a problem. Please note, however, that this chapter is not a comprehensive guide to aquatic pest identification. Consult a plant identification book, a scientist, or your local extension educator to help you confidently identify each problem organism.

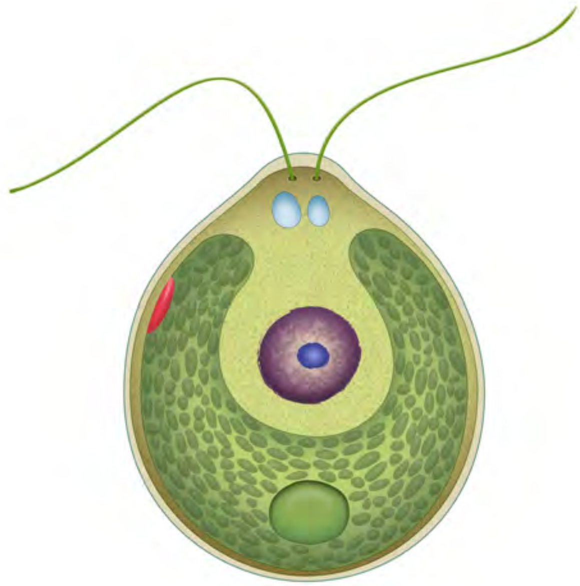
ALGAE

Planktonic algae

Chlamydomonas, *Chlorella*, *Euglena*, *Closterium*, *Anacystis*, etc.



Euglena[17]



Chlamydomonas[18]

Description

- Microscopic organisms which when present in great numbers are called an algae bloom

Habitat

- Occur in all types of water bodies and are important in the aquatic food chain

Biology/Ecology

- Least abundant in winter or during other cold periods when temperature inhibits their growth

Damage

- Large blooms can cause overshading of desirable plants and may also cause oxygen depletion, leading to fish kills

Filamentous algae

Spirogyra, *Anabaena*, *Oscillatoria*, etc.

Spirogyra[19]

Description

- Single algal cells that form long visible chains, threads, hairs, or filaments
- Filaments often intertwine to form a mat resembling wet wool

Habitat

- Occur in all types of water bodies

Biology/Ecology

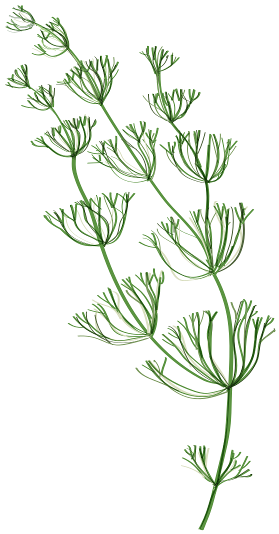
- Blooms start to grow along the bottom in clear shallow water in spring, where light can penetrate to the bottom
- Cells and filaments are often attached to structures like rocks or aquatic plants
- As reproduction increases, mats of algae may float to the surface; these mats are often referred to as “pond scum”

Damage

- Sudden die-offs of dense mats can cause water quality problems and oxygen depletion, as well as aesthetic and odor issues as the algae decompose

Erect algae

Chara, Nitella



Nitella[20]

Description

- Submerged erect algae often confused with submerged flowering plants
- Chara has a foul, musty, garlic-like odor and a grainy or crunchy texture, with whorled branches with 6–16 small branchlets around each node
- Nitella is soft to the touch and does not smell, and has forked, bushy branches

Habitat

- Erect algae can be found in all types of aquatic environments and bloom across ponds wherever nutrients are available

Biology/Ecology

- Blooms begin to spread in early spring as water temperatures increase

Damage

- Erect algae can cause problems for swimmers and boaters if large dense blooms are allowed to exist
- Large-scale diebacks can cause oxygen depletion and fish kills

Didymo

Didymosphenia geminata

Didymo[21]

Description

- INVASIVE
- Technically a diatom, a type of unicellular algae encased in a layer of silica
- When present in large numbers, didymo forms brown mats in the water, or long flowing streamers of algae that may appear white at the end
- Brown, beige, or white, but not green, and is scratchy or rough to the touch

Habitat

- Both epiphytic (attaches to plants) and epilithic (attaches to rocks)
- Found in freshwater streams and lakes with low nutrient content, in clear, shallow, warm water
- High light levels are required for its establishment

Biology/Ecology

- Grows by cell division, which means that a single cell can start a new colony
- Utmost care should be taken to prevent the spread of didymo on boats and other aquatic equipment

Damage

- Can form a thick brown layer in the water that smothers rocks and plants, reducing good habitat for fish, invertebrates, and plants, and excluding other diatoms
- Significant aesthetic effects are also a concern

FLOATING PLANTS

American lotus

Nelumbo lutea

American lotus[22]

Description

- Rooted floating; a perennial plant that looks like a water lily
- Round, bluish leaves up to 2 ft in diameter
- Flowers can be 10 inches across, yellow to yellowish-white with more than 20 petals; flower's center is cone-shaped

Habitat

- Not yet present in our region; exists in bordering states
- Invades floodplains of major rivers, ponds, lakes, pools in marshes and swamps, and backwaters of reservoirs

Biology/Ecology

- Can form large colonies
- Spreads both by seeds and by its large, fleshy rhizomes
- Flowers from late spring to mid-summer

Damage

- Can be extremely aggressive in appropriate conditions, crowding out other species and lowering water quality

Bladderwort

Utricularia spp.

Bladderwort[23]

Description

- Floating; no roots, but flowers on erect stems above the water
- Flowers are yellowish, with three lobes and a spur beneath
- Petioles are full of air, allowing them to float
- Leaves whorled, with 4–10 lateral forking leaves, giving the plant a delicate appearance

Habitat

- Usually found in quiet, shallow, acidic waters
- Found in lakes, streams, and wet marshes; can survive in water up to 6 ft deep

Biology/Ecology

- Bladderworts bear small oval bladders on their submerged leaves that trap and digest small aquatic creatures
- Blooms from May–September

Damage

- Forms dense floating mats that can impede boaters and swimmers
- Decomposing ends of the plant may cause oxygen depletion

Duckweed

Lemna spp.

Duckweed[24]

Description

- Floating; very small, light green, free-floating plant
- 1–3 leaves or fronds up to ⅛-inch long
- A single root protrudes from each frond

Habitat

- Grow in dense colonies in quiet water undisturbed by wave action
- Prefers mesotrophic and eutrophic waters

Biology/Ecology

- Often found mixed with mosquito fern or watermeal
- Flowers from late spring to early fall

Damage

- Aggressive invaders of ponds
- Oxygen depletions and fish kills can occur

Fragrant water lily

Nymphaea odorata

Fragrant water lily[25]

Description

- Rooted floating; consists of round leaves on flexible stalks arising from large thick rhizomes
- Leaves are bright green, 6–12 inches in diameter, with a slit along 1/3 of the leaf
- Very fragrant bright white flowers with 25 or more petals and yellow centers arise on separate stalks, floating above the water

Habitat

- Will grow in acidic or alkaline ponds, lakes, sluggish streams and rivers, pools in marshes, ditches, canals, or sloughs

Biology/Ecology

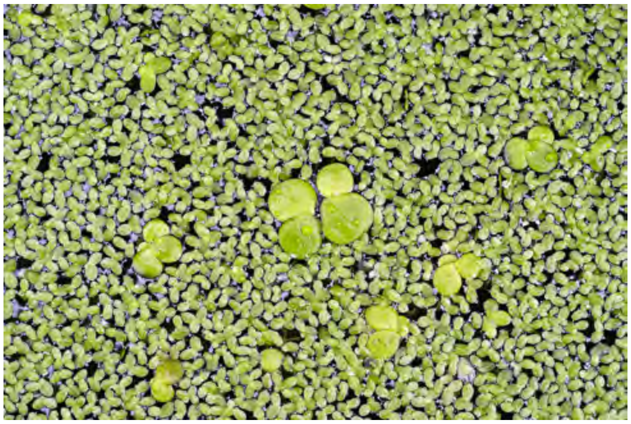
- Spreads by seed and rhizome
- Flowers from spring to early fall

Damage

- Impedes water movement, causes sediment buildup, decreases recreational quality of waterways

Giant duckweed

Spirodela polyrhiza



Giant duckweed[26]

Description

- Floating; leaves are ⅛–¼-inch long, with 1–4 light green leaves or fronds
- Three or more root hairs protrude from each frond

Habitat

- Prefers quiet, eutrophic waters of ponds and lakes and slow-moving streams

Biology/Ecology

- Grows in dense colonies
- May be mixed with other duckweeds, mosquito fern, or watermeal
- Rare flowering from summer to early fall
- Reproduces by budding

Damage

- If colonies cover the surface of the water, oxygen depletions and fish kills can occur
- Large colonies make recreational use less desirable

Mosquito fern

Azolla spp.

Mosquito fern[27]

Description

- Floating; small fern 1–2 inches wide
- Leaves overlap, giving the surface a quilted appearance
- A single root-like structure protrudes from each stem
- Plants vary in color from green to red

Habitat

- Generally found in quiet ponds protected from wind action
- Mosquito ferns can be aggressive invaders in quiet ponds and are often found mixed in with duckweeds or watermeal
- Usually found in stagnant waters of ponds, lakes, marshes, swamps, and streams

Biology/Ecology

- Reproduces by spores or by fragmentation

Damage

- If these fern colonies cover the surface of the water, oxygen depletions and fish kills can occur

Water hyacinth

Eichhornia crassipes

Water hyacinth[28]

Description

- INVASIVE
- Floating; several leaves in rosettes are connected by stolons; prominent black roots hang from each rosette
- Leaves are thick, leathery, 1–5 inches long by 1–4 inches wide, elliptical with parallel veins, held up by long, spongy petioles
- Several blue to purple bluish flowers with a yellow blotch are clustered on tall spikes
- Fruits are many-seeded capsules

Habitat

- Found in ponds, canals, marshes, lakes, sloughs, and oxbows

Biology/Ecology

- Reproduction primarily from runners or stolons
- Seeds can survive during periods of drought
- May be eliminated from certain areas by particularly harsh winters

Damage

- Dense growth clogs canals and water intakes and restricts navigation in rivers and lakes
- Can negatively impact water quality and exclude native vegetation

Water lettuce

Pistia stratiotes

Water lettuce[29]

Description

- INVASIVE
- Floating; forms rosettes up to 5 inches across
- Leaves are oblong, shaped like spades, and light green with velvety hairs and many prominent longitudinal veins
- Flowers are few and enclosed in a leaflike hood

Habitat

- Usually found in lakes and rivers, survives in wet mud
- Prefers slightly acidic water with moderate hardness

Biology/Ecology

- Spreads by fragments or even whole plants that can be transported on boats or fishing equipment

Damage

- Forms dense mats on the water surface, blocking waterways
- Lowers oxygen concentrations and sunlight penetration
- May be a breeding ground for mosquitoes

Watermeal

Wolffia columbiana, W. borealis

Wolffia spp.[30]

Description

- Floating; very small (less than 1 mm) light green rootless plant

Habitat

- Prefers quiet, eutrophic waters undisturbed by wave action

Biology/Ecology

- Perennial; flowers (rarely) from summer through early fall
- Grows in dense colonies, often found mixed with duckweed and mosquito fern

Damage

- Watermeal can be an aggressive invader of ponds
- If colonies cover the surface of the water, oxygen depletions and fish kills can occur

Watershield

Brasenia schreberi

Watershield[31]

Description

- Floating; leaves are small (5 inches in diameter) oval to elliptical, with no slit at the stalk.
- Leaves have a distinctive gelatinous slime on the underside.
- Leaves are green on top, but stems and leaf undersides are reddish-purple.
- Flowers are small (up to ¾-inch), dull-red with 3–4 petals, and rise above the surface.

Habitat

- Prefers soft, acidic waters below 2000 ft elevation

Biology/Ecology

- Perennial
- May form very large colonies
- Flowers from late spring through summer

Damage

- Covers water, reducing light penetration and oxygen concentrations
- Chokes waterways and reduce the recreational value of the water body

Yellow pond lily (spatterdock)

Nuphar lutea

Yellow pond lily

Description

- Rooted floating; leaves arise from a large, spongy rhizome
- Leaves are 8–16 inches long by 10 inches wide, heart-shaped, with a slit from the stem
- May float on the surface or stand above on thick round stalks
- Flowers are spherical with 6–9 yellow petals
- Fruit are oval with a flat top, greenish or yellow

Habitat

- Prefers slow-moving or still waters of ponds, lakes, streams, ditches, especially where silty or organic soils are present

Biology/Ecology

- Perennial; spreads from seeds and rhizomes
- Flowers throughout the summer

Damage

- Crowds out native species, impedes water flow and recreational water use

SUBMERGED PLANTS

Hydrilla

Hydrilla verticillata

Hydrilla[32]

Description

- INVASIVE
- Submerged; healthy leaves are bright green, while stressed leaves may be brown or yellow
- Long, slender stems
- Leaves are up to 2 cm long, have a midrib on the underside with one or more sharp teeth along it, and leaf margins are saw-toothed, found with whorls of 4–8
- Often confused with native elodea and Brazilian elodea, but leaves of other species are usually much smoother than hydrilla
- Will produces tubers, unlike most other similar species (elodea, Brazilian elodea)
- Roots to the bottom in depths up to 25 ft
- If present, flowers are fine, white, and appear singly on threadlike stalks

Biology/Ecology

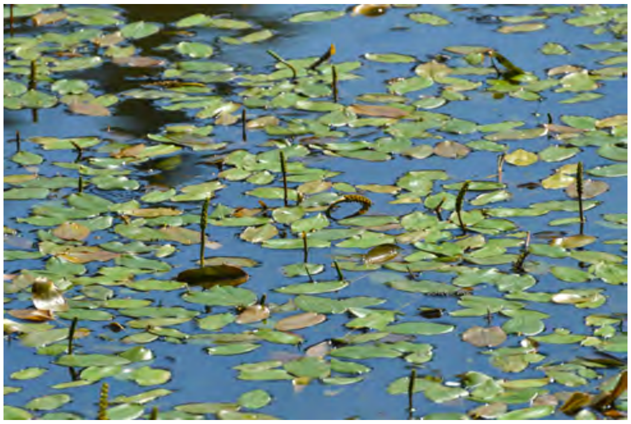
- Perennial
- Reproduces through vegetative fragments, tubers, turions, and possibly seed
- Both dioecious and monoecious populations are found in the U.S.
- Only female dioecious plants are present in the U.S., and do not reproduce sexually
- Monoecious hydrilla will flower, and may be capable of producing viable seed
- In northern areas, monoecious hydrilla will form tubers and turions in mid to late summer

Damage

- Forms dense, single-species stands that impact water flow, sedimentation, water quality, and recreational use

American pondweed

Potamogeton nodosus



American pondweed[33]

Description

- Submerged; pondweed has both floating and submerged leaves in an alternate pattern
- Leaves are elliptical to oval, 4–7 inches long and 2 inches wide, standing on long petioles
- Fruits appear on brownish-reddish spikes that stand above the water's surface

Habitat

- Clear to turbid waters of lakes, streams, and ditches

Biology/Ecology

- Perennial, flowers from summer through fall
- Spreads by seeds and rhizomes

Damage

- Plants may grow rampantly and invade deep water, pushing out more diverse species

Brazilian elodea (egeria)

Egeria densa

Brazilian Elodea[34]

Description

- INVASIVE
- Submerged; leaves and stems are a bright green, and whole plants appear very leafy
- Leaves are minutely serrated, 1–3 cm long and very thin, found in whorls of 4–8
- Flowers are white and very small, with 3 petals, rising above the water's surface
- Roots to the bottom in depths up to 20 ft

Habitat

- Found in both still and flowing waters, lakes, ponds, ditches,and streams

Biology/Ecology

- Perennial
- Reproduces only vegetatively
- Growth begins when water temperatures reach 50°F
- Flowering occurs in the late spring and again in the fall
- During the summer, profuse branching forms a dense canopy

Damage

- Forms dense, single-species stands that restrict water flow, trap sediment, and impact water quality

Coontail

Ceratophyllum demersum

Coontail[35]

Description

- Submerged; dark olive green, rootless, forms dense colonies
- Leaves are stiff, whorled, serrated
- Tips of branches are crowded with leaves, giving it a feathery, fur-like appearance
- Flowers are tiny, and appear at the joint between the leaf and stem

Habitat

- Prefers fresh to slightly brackish waters in lakes, streams, ponds, ditches, and marshes, in standing to slow-moving waters

Biology/Ecology

- Perennial; reproduces by seed and fragmentation
- Flowers from spring to early fall

Damage

- Large stands will decrease the recreational and habitat uses of the water body, and will also crowd out more desirable or appropriate species

Curlyleaf pondweed

Potamogeton crispus

Curlyleaf pondweed[36]

Description

- INVASIVE
- Submerged; lance-shaped, reddish-green leaves with wavy and finely toothed margins
- Stems are branched and somewhat flattened
- Flowers are very small and inconspicuous, arranged in a dense spike on a curved stalk

Habitat

- Grows in fresh to slightly brackish waters; can grow in waters up to 12 ft deep
- Prefers quiet alkaline and even eutrophic waters of lakes, streams, and ponds.

Biology/Ecology

- Perennial; flowers from spring through summer
- Tolerates low light and low water temperatures
- Produces turions in late spring, then dies back, leaving only fruit and turions which survive the summer
- Turions germinate in fall, and a very small plant overwinters, growing quickly again as temperatures rise in the spring

Damage

- Grows in dense beds which may outcompete native aquatics
- Dense surface mats also interfere with recreational water use
- May also cause an increase in phosphorus concentrations and oxygen depletion due to its midsummer dieback

Freshwater eelgrass (wild celery)

Vallisneria americana

Eelgrass[37]

Description

- Submerged; rooted plant with long, thin, ribbon-like leaves about ½-inch wide and commonly 3–4 ft long
- Vein pattern is distinctive, resembling celery
- Single white flowers grow to the surface on long stalks; fruits are capsules resembling bananas

Habitat

- Found in flowing water
- Prefer ponds, lakes, and streams at depths up to 12 ft

Biology/Ecology

- Vast rhizome system allows it to form dense colonies and exclude other submerged plants
- In winter, buds or turions form at the plant's base; in spring, these buds grow and release stolons, which produce a new plant
- Flowers from late summer to early September

Damage

- Clogs waterways, wraps around boat propellers, reduces overall recreational quality of the water body

Elodea

Elodea canadensis

Elodea[38]

Description

- Submerged; rooted, multibranched plant that can survive and grow as floating fragments
- Leaves are dark green, blade-like, with toothed margins, about ½ inch long, growing in whorls of 3

- Flowers have 3 white petals with a waxy coating

Habitat

- Prefers calcareous waters of lakes and rivers and fine sediment for rooting

Biology/Ecology

- Perennial; flowers through summer

Damage

- Can become an impenetrable mat, especially near shorelines, making recreation and boating difficult
- Large mats can break off and float on the surface, shading the bottom and causing oxygen depletions

Eurasian watermilfoil

Myriophyllum spicatum

Eurasian Watermilfoil[39]

Description

- INVASIVE
- Submerged
- Long branching stems with feather-like whorled leaves, rooted

Habitat

- Prefers lakes, ponds, shallow reservoirs, and low energy areas of rivers and streams, in water up to 7 ft deep
- Common in areas disturbed by nutrient loading, intense plant removal, or frequent motorboat use
- Tolerates a range of temperatures

Biology/Ecology

- Perennial; flowers emerge in early summer
- Survives winter as root stalks or sometimes plant fragments
- In late summer and fall, plants fragment easily

Damage

- Rapidly colonizes ponds, lakes, or areas of slow-moving water
- Creates dense mats of vegetation, shades out other native plants, diminish habitat and food resources for fish and birds, and decreases oxygen levels in the water as the plant decays

Horned pondweed

Zannichellia palustris

Horned pondweed[40]

Description

- Submerged; long thin stems produce long, hair-like leaves at nodes
- Roots are long and threadlike
- Seeds are distinctively horn-shaped
- May be easily confused with Sago Pondweed
- Opposite leaves

Habitat

- Present throughout the region
- Prefers brackish or freshwaters of lakes, streams, or estuaries

- Prefers shallower waters, but will grow in water up to 15 ft deep

Biology/Ecology

- Perennial; flower in spring and summer

- Begins to grow early in spring, releases seeds by June and dies back

Damage

- Chokes out other plants, creates problems for boaters, reduces the recreational quality of water bodies

Illinois pondweed

Potamogeton illinoensis

Illinois Pondweed[41]

Description

- Submerged; leaves are blade-like, 1–7 inches long
- Fruits are greenish, ½–3 inches long, located on the tip of stems that protrude above the water surface

Habitat

- Prefer alkaline waters of lakes, streams, ponds, and ditches

Biology/Ecology

- Perennial; flowering and fruiting late summer through fall

Damage

- Plants may grow rampantly and invade deep water, pushing out more diverse species

Northern watermilfoil

Myriophyllum spicatum

Northern watermilfoil[42]

Description

- Submerged; dark green, feathery leaves are grouped in fours around a hollow stem which is usually buff or pink colored.
- Leaves are made up of 5–10 pairs of leaflets
- Unlike Eurasian watermilfoil, this species forms winter buds, groups of small, dark, brittle leaves, in late fall to winter

Habitat

- Grows in depths from 1–20 ft
- Prefers lakes with fairly clear water and soft sediment soils

Biology/Ecology

- Perennial; flowers summer through fall

Damage

- May occur in dense patches, crowding out all other growth

Parrotfeather

Myriophyllum aquaticum

Parrotfeather[43]

Description

- INVASIVE
- Submerged or emergent; grows best rooted to substrates, but can occur as a floating plant in deeper waters
- Bright green freshwater herb with feather-like leaves arranged around the stem in whorls of 4–6
- Emergent or submersed leaves differ in color and size
- Emergent stems can grow as much as a foot above the water

Habitat

- Prefers lakes pond, streams, and canals, and is highly adapted to high nutrient environments
- Colonizes slow moving or still waters

Biology/Ecology

- Spreads exclusively by fragmentation
- Tough rhizomes may be transported long distances if attached to boats or trailers
- Shoots begin growing from overwintered rhizomes in spring
- Flowers in spring, though some plants also flower in fall

Damage

- Can seriously change the physical and chemical characteristics of lakes and streams
- Infestations can alter aquatic ecosystems by shading out the algae in the water column that serve as the basis of the aquatic food web
- Provides choice mosquito larvae habitat
- Dense infestations may cause flooding and may restrict recreational opportunities

Sago pondweed

Stuckenia pectinata

Sago pondweed[44]

Description

- Submerged; stems long, thin, and highly branched, with thin filament-like leaves about 1/16 inch wide and 2–12 inches long
- Leaves grow in thick layers and originate from a sheath
- Fruit is nut-like, ⅛-inch long
- May be easily confused with Horned Pondweed
- Alternate leaves

Habitat

- Prefers brackish to alkaline waters of lakes, rivers, streams, and estuaries
- Can tolerate turbid conditions

Biology/Ecology

- Perennial; flowers summer through fall

Damage

- Clogs waterways, crowds out more desirable plants

Small pondweed

Potamogeton pusillus

Small pondweed[45]

Description

- Submerged; delicate stems with long, narrow leaves with no petioles, 2–3 inches long
- Flowers appear in 1–4 whorls on tiny spikes
- Roots are fibrous

Habitat

- Wide tolerance of water conditions, including brackish waters

Biology/Ecology

- Perennial.
- Seeds and winter buds form at lateral branch tips near leaf bases

Damage

- Like other pondweeds, this species can take over a water body, decreasing diversity and lowering the recreational and habitat quality of the area

Southern naiad

Najas guadalupensis

Southern naiad[46]

Description

- Submerged; leaves are dark green to greenish-purple, ribbon-like, in a whorl of 3, less than ½-inch wide and ⅛-inch wide
- Single seeds are found encased in the leaf sheath
- Flowers are found at the base of leaves but cannot be seen without magnification

Habitat

- Prefers waters deeper than 3 ft, with gravelly or sandy soil

Biology/Ecology

- Annual; reproduces by seed and fragmentation

Damage

- Dense beds block waterways, impede drainage, disrupt recreational activities, choke hydro turbines
- Out-competes native species

Spiny naiad (brittle naiad, marine naiad)

Najas marina

Spiny naiad[47]

Description

- Submerged; resembles southern naiad except that the leaves are highly toothed
- Leaves are 1¼ inches long and ¼ inch wide, with several leaves at each node
- Flowers are ⅛–¼ inch long, in the leaf axis

Habitat

- Prefers brackish or highly alkaline waters of lakes and ponds up to 3,000 ft elevation

Biology/Ecology

- Perennial; flowers from summer through fall

Damage

- Like southern naiad, dense beds of this species block waterways, impede drainage, and disrupt recreational activities
- Out-competes other species

Variable-leaf milfoil

Myriophyllum heterophyllum

Variable-leaf milfoil[48]

Description

- Submerged; reddish, branched stems with two different leaf types
- Above-water leaves stiff, bright green, and serrated, ⅜-1¼ inches long and very thin; submerged leaves are feather-like and flaccid, longer and wider, with 8–18 thin segments
- Flowers are ⅛-inch long with 4 reddish oval petals in whorls

Habitat

- Prefers shallow waters but will grow in water up to 16 ft deep, especially prefers silty sediments

Biology/Ecology

- Perennial; reproduces by seed and fragmentation

Damage

- An aggressive invader, and can completely take over shallow ponds

Water buttercup

Ranunculus longirostris

Water buttercup[49]

Description

- Submerged; leaves are variable, but always alternate
- Submerged leaves branch into 20 thread-like segments, ½-2 inches wide and attached to the stem by short petioles
- Floating leaves are flat and scalloped with 3–5 lobes
- Flowers single, on stalks that rise above the water surface, ½ inch wide with a yellow center and 5 white petals

Habitat

- Found in ponds, lake margins, ditches, and streams

Biology/Ecology

- Perennial; blooms April-June

Damage

- Forms dense mats, can choke shallow, slow-moving areas, pushing out more desirable vegetation

EMERGENT PLANTS

Arrowleaf tearthumb

Polygonum sagittatum

Arrowleaf tearthumb[50]

Description

- Emergent; reaches 1 ft high
- Leaves broad, arrowhead shaped with two prongs at the base
- Lower leaves have longer, prickly petioles
- Flowers are small, white or light pink, arranged in small spherical clusters on short stalks

Habitat

- Found in moist shaded sites, meadows, pastures, wetlands, swamps, and shorelines

Biology/Ecology

- Perennial; flowers from July-October

Damage

- Crowds out other species

Cattail

Typha spp.

Cattail[51]

Description

- Emergent
- Flat leaves grow 5–10 ft in height. Flowers forms a dense, dark brown cigar shape called a catkin at the end of the stem

Habitat

- Grows in partially submerged or boggy soils, in pond edges and in slow-flowing water

Biology/Ecology

- Spreads rapidly from free-floating seeds and rhizomes
- Flowers from spring all through summer

Damage

- Impedes water movement, causes sediment buildup, and makes navigation difficult
- Aesthetics are also compromised, as well as the recreational value of the water body

COMMON REED

Phragmites australis

Common reed[52]

Description

- Emergent
- Cane-like grass that grows from 12–15 ft in height and forms dense stands
- Stems round and hollow with flat leaves along their length
- Leaves may be up to 2 ft long and 2 inches wide
- Seed-head highly branched, 8–16 inches long
- Hairs growing from flowers give seed head a silky appearance

Habitat

- Grows in wet or muddy ground along waterways, in saline or freshwater basins, and in ditches or sloughs

Biology/Ecology

- Propagates via seed or rhizomes

Damage

- Spreads very quickly and is difficult to eradicate
- Can change nutrient cycles and hydrology in water bodies, while crowding out other species, decreasing the biodiversity and natural habitat available to aquatic animals

GIANT REED

Arundo donax

Giant reed[53]

Description

- INVASIVE
- Emergent; tall grass that can grow to over 20 ft high
- Fleshy creeping roots form compact masses from which tough, fibrous roots emerge
- Leaves are 1–2 ft long and 1–2 inches wide
- Flowers are borne on a 2 ft long dense plume

Habitat

- Becomes established in ditches, streams, and riverbanks, and grows best on well-drained soils; tolerates salinity

Biology/Ecology

- Perennial; flowers from August-September
- Reproduction is primarily vegetative, through rhizomes

Damage

- Chokes water channels, crowds out native plants, interferes with water movement, and reduces habitat for wildlife
- Ignites easily and can create intense fires

GREAT OR SOFT-STEMMED BULRUSH

Schoenoplectus tabernaemontani

Great bullrush[54]

Description

- Emergent; unbranched, 4–8 ft tall dull green stems with a soft spongy interior
- Leaves are small and wrap around the stem
- Flowers occur in a large feathery bunch at the end of the stem, 6 inches long
- Root system fibrous, with strong rhizomes

Habitat

- Prefers wet conditions in soil that is mucky or sandy
- Found in wet prairies, marshes, swamps, on the borders of lakes and ponds, and in ditches
- Thrives in wetlands with a history of disturbance

Biology/Ecology

- Perennial, wind-pollinated; flowers in summer
- Propagates easily from rhizomes

Damage

- Clogs waterways, impedes boats, decreases recreational usefulness of water body

PURPLE LOOSESTRIFE

Lythrum salicaria

Purple loosestrife[55]

Description

- NOXIOUS weed in all states in region
- Emergent; erect herb with a square woody stem and whorled, lance-shaped leaves
- Leaves and stems are usually covered in downy hairs
- Flowers are showy and purple, with 5–7 petals, and arise on tall flower spikes

Habitat

- Invades wetlands, marshes, river and streambanks, pond edges, reservoirs, and ditches

Biology/Ecology

- Perennial; flowers from June-September
- Requires pollination by insects
- Reproduces primarily by seed, but also from rhizomes

Damage

- Readily adapts to natural and disturbed wetlands, outcompeting native grasses and other plants that provide more nutrition for wildlife
- Forms dense stands that restrict native wetland plant species

SMARTWEED

Polygonum pensylvanicum, P. hydropiperoides

Smartweed[56]

Description

- Emergent; forms dense colonies; may grow to 3 ft tall
- Jointed stems have swollen leaf nodes surrounded by a sheath
- Leaves are lance-shaped, up to 4 inches long and less than ½ inch wide
- Flowers are on spikes at the end of stems; start out greenish and turn white or light pink
- Fruit is flat, triangular, dark brown to black

Habitat

- Reported throughout the region
- Shallow water or moist soils in disturbed places, ditches, riverbanks, cultivated fields, shorelines of ponds and reservoirs

Biology/Ecology

- Perennial; flowers from May-December

Damage

- Dense stands can constrict water movement, collect sediment, and restrict recreational use

TAMARISK (SALT CEDAR)

Tamarix spp.

Tamarisk[57]

Description

- INVASIVE
- Emergent; grows up to 15 ft tall
- Leaves are small, scale-like, gray-green and overlap along the stem, and are often coated with salt crystals
- Bark is smooth and reddish on young plants, turning brown and furrowed with age
- Flowers pink to white in 2 inch spikes at branch tips

Habitat

- Invades streambanks, sandbars, lake margins, wetlands, moist rangelands and saline environments

Biology/Ecology

- Deciduous shrub
- Flowers May–September
- Stems and leaves of mature plants secrete salt
- Salt secretions inhibit the growth of other plants
- A mature plant can absorb up to 200 gallons of water per day

Damage

- Crowds out native species, diminishes water tables, and interferes with hydrologic processes

WATER CRESS

Nasturtium officinale

Watercress[58]

Description

- INVASIVE
- Emergent; a tangle of stems and leaves held above the water
- Leaves are compound, with a central stalk and several round leaflets with slightly wavy edges
- Leaves have a strong peppery taste
- Flowers are small, with 4 white petals, clustered at the end of stems
- Fruits are thin, slightly curved cylindrical pods

Habitat

- Prefers cold, flowing water and limey, gravelly, sedimentary soil

Biology/Ecology

- Perennial; flowers from March-October
- Reproduces by seed and stem fragments
- Eaten by ducks, muskrat, and deer, and is grown commercially

Damage

- Forms large, tangled winter-green masses that can choke water inlets or outlets

WATER PENNYWORT

Hydrocotyl spp.

Water pennywort[59]

Description

- Emergent; small plant seldom exceeding 10 inches in height
- Creeping stems give rise to round leaves with toothed margins up to 2 ½ inches in diameter
- Flowers are borne on separate stalks taller than other leaves; white to greenish-white, very small, arising from a single point on the stalk

Habitat

- Prefers moist conditions

Biology/Ecology

- Perennial; reproduces by seed or shoots from stolons

Damage

- Can spread across moist soil or form floating mats on the water's surface
- Mats can break off and form floating islands

YELLOW LOOSESTRIFE

Lysimachia vulgaris

Yellow loosestrife[60]

Description

- Emergent; can grow over 3 ft tall
- Stems and leaves are covered with soft hairs
- Leaves are lance-shaped, 2–4 inches long, occur in opposite or whorled arrangements, dotted with black or orange glands
- Flowers are yellow, with 5 petals, and resemble primrose, occurring at the top of the plant
- Fruit is a dry capsule

Habitat

- Prefers moist habitats, such as wetlands, wet woods, lake shores, and river banks

Biology/Ecology

- Perennial; spreads by thick rhizomes and seeds
- Flowers from July–September

Damage

- Crowds out native species, clogs waterways, and inhibits recreational use

FISH

COMMON CARP

Cyprinus carpio

Common carp[61]

Description

- INVASIVE
- Can reach 4 ft long and weigh over 80 lbs, though normally smaller (10–12 lbs)
- A heavy-bodied minnow with barbels on either side of the upper jaw
- Color varies from brassy green or yellow, to golden brown, or even silvery; the belly is usually yellowish-white
- Long dorsal fin base

Habitat

- Prefers large, slow-moving water bodies with warmer water (70°F) but can survive virtually anywhere and will overwinter under ice

Biology/Ecology

- Carp are omnivorous, feeding on both plants and animals. and can gain 1 lb or more per month in good conditions
- Spawning occurs from May-July
- Eggs are sticky and deposited on submerged vegetation and hatch in less than a week

Damage

- Heavy feeders, reducing the amount of prey available to native species, resulting in decreased biodiversity
- Disturbs sediments when feeding, increasing turbidity

FLATHEAD CATFISH

Pylodictis olivaris

Flathead catfish[62]

Description

- INVASIVE
- Can grow to more than 100 lbs
- Broad, flat head and projecting lower jaw
- Tail fin outline is square or slightly notched
- Coloration can vary, but most have an olive cast to their back and sides with dark brown to yellow-brown mottling
- Belly is yellowish-white, and eyes are relatively small

Habitat

- Prefer reservoirs, lakes, rivers, and large streams, thriving in deep pools with logs and submerged debris cover

Biology/Ecology

- Spread mainly by anglers who intentionally release flatheads into new watersheds; very popular sport fish
- Males dig nest cavities into river banks where females will lay their eggs in summer, then defend the eggs against other fish

Damage

- Ferocious feeding habits, large size, and its ability to swim long distances in a short

time make this species a great threat to biodiversity
- Feeds on sunfish, crayfish, shad, crabs, and American eels, while crowding out native catfish populations

AMPHIBIANS

AMERICAN BULLFROG

Rana catesbeiana

American bullfrog[63]

Description
- INVASIVE
- Largest frog in North America; may reach 6 inches in length
- Large and conspicuous tympanic membrane (eardrum)
- Hind feet completely webbed except last joint of center toe
- Ranges in color from dark olive to pale green, and may have spots or mottling
- Underside is dark cream to yellow
- Tadpoles are greenish to yellow with many dark spots
- Call is a deep "jug-o-rum" or "br-wum" bellow

Habitat
- Highly aquatic and never strays far from a permanent water source; marshes, lakes, and ponds included

Biology/Ecology
- Breeds from February-July in permanent water bodies
- Eggs spread out in a large thin sheet over 12 inches in diameter, which attaches to submerged vegetation
- Tadpoles eat organic debris, algae, plant tissue, and small invertebrates
- Adults eat whatever can be swallowed, including snakes, birds, fish, crawfish, and other frogs

Damage
- Preys on native frogs and is responsible for the decline of several species, including frogs, snakes, and turtles, decreasing biodiversity

AFRICAN CLAWED FROG

Xenopus laevis

African clawed frog[64]

Description
- INVASIVE
- Only member of genus with clawed toes
- Flat body with a relatively small head; reaches 4 inches long
- Skin is smooth, with mottled hues ranging from olive brown to gray, while the underside is a creamy white color

- No tongue, teeth, eyelids, or tympanic membranes
- Four claws on the forefeet and five on the hindfeet

Habitat

- Very salt tolerant
- Adults can survive in water as cold as 33°F
- Inhabits rivers, lakes, ponds, marshes, ditches, and flooded areas

Biology/Ecology

- Preys on zooplankton, crustaceans, and invertebrates.
- Tadpoles are gilled and aquatic, reach maturity in 6–10 months
- Eggs are released singly and adhere to vegetation

Damage

- Causes declines in native amphibian and fish species
- May be toxic to predators
- Dense populations can increase water turbidity

ADDITIONAL RESOURCES

Aquatic and Riparian Weeds of the West. J. DiTomaso and E. Healy. University of California Agriculture and Natural Resources: 2003. *Provides information on weed identification, habitats, distribution, and control methods, with color photographs.*

Biology and Control of Aquatic Plants: a Best Management Practice Handbook. L.A. Gettys, W.T. Haller, and M. Bellaud, eds. 2009. Aquatic Ecosystem Restoration Foundation. Marietta GA. 210 pages. Available at: http://www.aquatics.org/bmp.html.

Field Guide to Survey and Manage Freshwater Mollusk Species. T.J. Frest and E.J. Johannes. BLM, USFWS, and USFS: 1999. Available at: http://www.blm.gov/or/plans/surveyandmanage/files/01-aquatic_guide.pdf. *Provides identification guides and management strategies for mollusks in the United States.*

USDA PLANTS Database. USDA PLANTS Database. http://plants.usda.gov. P*rovides standardized information about nearly every species of plant in the U.S., including names, plant symbols, checklists, distributional data, species abstracts, characteristics, images, crop information, automated tools, onward Web links, and references. species abstracts, characteristics, images, crop information, automated tools, onward Web links, and references.*

Department of Agriculture Pesticide Programs. *This department may conduct exams, issue licenses, conduct inspections, investigate complaints of pesticide misapplication by commercial applicators, or require technician training and continuing education.* *See page 1.*

State Pesticide Safety Education Programs. *These programs have many pesticide education resources including fact sheets, handbooks, training guides, and training videos.* *See page 2.*

TECHNICAL APPENDIX

Use this appendix as a reference for studying.

FORMULAS

Percent deviation of sprayer nozzles:

$$\% \text{ Deviation} = \frac{\text{average nozzle output} - \text{individual nozzle output}}{\text{average nozzle output}} \times 100$$

Surface acres:

$$\text{Surface acres} = \frac{\text{length in ft} \times \text{width in ft}}{43{,}560 \text{ sq ft per acre}}$$

Acreage of a rectangular area:

$$\text{Area of a rectangle} = \frac{\text{length} \times \text{width}}{43{,}560 \text{ sq ft per acre}}$$

Acreage of a circular area:

$$\text{Acreage of a circular area} = \frac{3.14 \times \text{radius}^2}{43{,}560 \text{ sq ft per acre}}$$

Acreage of a triangular area:

$$\text{Acreage of a triangular area} = \frac{1/2 \times \text{base} \times \text{height}}{43{,}560 \text{ sq ft per acre}}$$

Area of an irregularly shaped water body, using the graph paper method:

$$\text{Area of lake} = \text{area of rectangle} \times \text{fraction occupied by lake}$$

Effective swath width:

$$\text{Effective swath width} = \text{boom width} \times 2$$

Herbicide needed to treat a given area:

$$\text{Herbicide needed} = \text{treatment rate} \times \text{acres to be treated}$$

Average depth:

$$\text{Average depth} = \frac{\text{sum of all measurements}}{\text{number of measurements}}$$

Volume:

$$\text{Volume} = \text{average depth in ft} \times \text{surface area in acres}$$

$$\text{Volume} = \frac{l \times w \times d}{\text{43,560 cubic ft per a.f.}}$$

Pounds ai needed for a given ppm:

$$\text{lbs ai needed} = \text{ppm} \times \text{water volume in a.f.} \times 2.7$$

PPM for a given amount of ai:

$$\text{ppm} = \frac{\text{lbs ai}}{\text{water volume} \times 2.7}$$

Converting ai and product in dry formulations:

$$\text{Amount ai} = \text{amount product} \times \text{\% ai}$$

$$\text{Amount product} = \frac{\text{amount ai}}{\text{\% ai}}$$

Converting ai and product in liquid formulations:

$$\text{lbs ai} = \text{gallons product} \times \text{lbs ai per gallon}$$

$$\text{Gallons product} = \frac{\text{lbs ai}}{\text{lbs ai per gallon}}$$

Converting recommended proportions to available tank size:

$$\text{Herbicide per tank} = \frac{\text{volume of spray tank} \times \text{given herbicide amount}}{\text{spray mix amount given}}$$

Pounds per acre (PPA):

$$\text{PPA} = \text{43,560 sq ft} \times \frac{\text{weight of collected material}}{\text{swath width} \times \text{course length}}$$

GPA =

$$\text{GPA} = \frac{\text{gallons per minute (GPM)} \times 5{,}940}{\text{miles per hour (MPH)} \times \text{nozzle spacing in inches}}$$

$$\text{GPA} = \frac{\text{gallons per minute (GPM)} \times 495}{\text{swath width in feet}}$$

Acres per minute (APM):

$$\text{APM} = \frac{\text{swath width} \times \text{distance traveled} \times 60^{*}}{43{,}560 \times \text{time to cover distance}}$$

Miles per hour (MPH):

$$\text{MPH} = \frac{\text{distance in feet} \times 60 \text{ minutes per hour}}{\text{time in seconds} \times 88 \text{ ft per minute at 1 MPH}}$$

Course length:

$$\text{Course length} = \frac{43{,}560 \text{ sq ft per acre}}{\text{swath width}}$$

Amount of adjuvant to add according to tank size:

Amount of adjuvant = % concentration × tank volume

Sprayer output:

Sprayer output = Duration of treatment (ECT) × Application rate GPM)

Clarity and Water Temperature Values:

Clarity Values		Water Temperature Values	
Clear	1.00	Hot (>30°C)	1.00
Turbid	1.25	Warm (24°–29°)	1.25
Muddy	1.50	Cold (18°23°)	1.50

Multiplier value = clarity value + water temp value

Amount of KMnO4 neutralizer to add:

Grams of KMnO4 = oz piscicide × multiplier value

For flowing water, the milliliters of product per minute:

Total mL product = mL product per minute × ECT

Total volume of product for the ECT:

```
Total mL product          =   mL product per minute × ECT
```

CONVERSION TABLES

Volume/Volume Mixtures			
Desired Concentration (%)	Desired Spray Solution (gallon)	Gallons to Mix of Product	Gallons to Mix of Water
0.5	25	0.125	24.88
0.5	50	0.25	49.75
1.0	25	0.25	24.75
1.0	50	0.50	49.60
1.5	25	0.375	24.62
1.5	50	0.75	49.25

Area — Volume — Length — Weight

Area

144 square inches .... 1 square foot

9 square feet .... 1 square yard

43,560 square feet .... 1 acre

4,840 square yards .... 1 acre

160 square rods .... 1 acre

640 acres .... 1 square mile

2.5 acres .... 1 hectare

Volume

1 tablespoon .... 3 teaspoons

1 fluid ounce .... 2 tablespoons

8 fluid ounces .... 16 tablespoons .... 1 cup

16 fluid ounces .... 2 cups .... 1 pint

32 fluid ounces .... 4 cups .... 1 quart

128 fluid ounces .... 4 quarts .... 1 gallon

1 liter .... 33.9 ounces .... 1.06 quarts

1 gallon .... 3,785 ml

Length

1 inch .... 2.54 centimeters .... 25.5 millimeters

1 foot .... 12 inches

1 yard .... 3 feet

1 rod .... 5.5 yards .... 16.5 feet

1 mile .... 320 rods .... 1,760 yards .... 5,280 feet

1 meter .... 39.4 inches .... 1.09 yards

1 kilometer .... 1,000 meters .... 0.62 miles

Weight

1 ounce .... 28.3 grams

1 pound .... 16 ounces .... 453.6 grams

2.2 pounds .... 1 kilogram .... 1,000 grams

1 ton .... 2,000 pounds .... 907 kilograms

1 metric ton .... 1,000 kilograms .... 2,205 pounds

LIST OF ABBREVIATIONS

A

A: acre
ae: acid equivalent
a.f.: acre feet
ai: active ingredient
APHIS: Animal and Plant Health Inspection
APM: acres per minute
ATV: all terrain vehicle

B

Bt: *Bacillus thuringiensis*

C

CET: concentration and exposure time
CFS: cubic feet per second
CWA: Clean Water Act

D

D: dust
DF: dry flowable
DO: dissolved oxygen
DOT: Federal Department of Transportation

E

E or EC: emulsifiable concentrate
ECT: effective contact time
EPA: Environmental Protection Agency
ESA: Endangered Species Act
ESPP: Endangered Species Protection Program
EW: concentrated emulsion

F

F: flowable
FAA: Federal Aviation Administration
FDA: Food and Drug Administration
FIFRA: Federal Insecticide, Fungicide, and Rodenticide Act
ft: feet

G

G: granular
GPA: gallons per acre
GPH: gallons per hour
GPM: gallons per minute
GPS: Global Positioning System
GUP: General Use

I

IPM: integrated pest management
IWRC: International Wildlife Rehabilitation Council

L

L: true liquid solution
lb: pound
LC50: 50% lethal concentration
LD50: 50% lethal dose

M

ml: milliliters
mm:millimetre
MPH: miles per hour

N

NPIC: National Pesticide Information Center
NWRA: National Wildlife Rehabilitators Association

O

OSHA: Occupational Safety and Health Administration
oz: ounces

P

PPA: product per acre
PPA: Plant Protection Act
PPE: personal protective equipment
PPM: parts per million
PSI: pounds per square inch

R

REI: restricted entry interval
RPM: revolutions per minute
RTU: ready-to-use formulation
RUP: restricted use pesticide

S

SC: suspension concentrate
SDS: Safety Data Sheet
SP: soluble powder
spp: species
sq ft: square feet
SWA: Surface Water Advisory

T

TFN: Trifluoromethyl-4-nitrophenol

U

ULV: ultra-low-volume concentrate
URC: University Resource Center
USDA: United States Department of Agriculture
USFWS: United States Fish and Wildlife Service
UV: ultraviolet light

W

WDG: water dispersible granules
WP: wettable powder
WPS: Worker Protection Standard
WPS: water soluble packets

GLOSSARY

Words in this glossary appear in boldface type the first time they appear in the study guide.

#

2,4-D: A systemic plant-growth regulator, very common for the control of broadleaved weeds.

A

absorption: Process by which pesticides move into plant, human, or animal tissues.

acid equivalent (ae): The amount of herbicide in a formulation (when measured in its acid form) that is principally responsible for the herbicidal effects and that is shown in the active ingredient statement on herbicide labels.

acidic: A solution with a pH below 7; that is, a solution with a high concentration of hydrogen ions.

acre-foot: The volume of water that will cover one acre to a depth of one foot, i.e., 43,560 cubic feet.

action threshold: Point at which pest populations or environmental conditions indicate that pest control action must be taken to prevent an economic loss.

active ingredient (ai): The chemical in a formulated product that is principally

responsible for the desired effects and that is shown as the active ingredient on pesticide labels.

acute toxicity: Harmful effects in an organism through a single or short-term exposure.

adjuvant: Any substance in a pesticide formulation or added to the spray mixture that enhances the pesticide's effectiveness.

adsorption: The attraction or adhesion of pesticide molecules to the soil particle surface.

aeration: Injection of air into bottom sediments or water column; can help reduce algal blooms.

agitator: A paddle, air, or hydraulic action to keep a pesticide chemical mixed in the spray or loading tank.

algaecide: A chemical specifically created for

the control or suppression of algae.

algal bloom: excessive algal growth; usually occur where abundant nutrients are reaching the water.

alkaline: A solution with a pH above 7; a solution with a low concentration of hydrogen ions.

amino acid synthesis inhibitor: Herbicide mode of action that inhibits amino acid synthesis which is necessary for the formation of plant proteins. Examples include the imidazolinones.

animal: A multi-cellular, non-photosynthetic, motile organism of the Kingdom Animalia, including mammals, birds, reptiles, insects, mites, nematodes, etc,

annual: A plant that completes its life cycle within one year and dies after reproducing.

annulus: plural -i: The annual rings that form in fish scales or bone sections.

antimycin: A piscicide that functions by inhibiting respiration in cells. Specific to fish.

application rate: The amount of pesticide applied to a site, usually expressed as a liquid or dry measure per unit area or volume, such as pounds or pints per acre, or per acre-foot.

aquatic pest: Any organism that compromises the aesthetic, environmental, economic, or recreational quality of a water body.

B

Bacillus thuringiensis (Bt): A bacterium that kills insects.

backpack sprayer: A sprayer that can be strapped on the back and used to apply liquid pesticides. The attached hose has a nozzle at the tip that can be aimed at the spot to be treated.

basic [see alkaline]

beaver: A primarily nocturnal, large, semi- aquatic rodent. Can cause problems due to dam-building and tree-cutting.

benthic barrier: A bottom cover made of growth-inhibiting materials. Prevents rooted plants from becoming established.

biennial: A plant that completes its growth in two years. The first year it produces leaves and stores food; the second year it produces flowers and seeds.

bioaccumulation: a process where a substance builds up in an organism after the organism consumes other organisms contaminated with the substance.

bioavailability: The relative amount of a substance in the environment that is available to be assimilated into the bodies of plants and animals.

bioconcentration: The accumulation of substances like pesticides in animal tissues at concentrations higher than that in the environment.

biological control or biocontrol: The use of living organisms, such as predators, parasitoids, and pathogens, to control pests.

biomagnification: The accumulation of substances like pesticides at each succeeding level in the food chain.

bipyridyliums: a group of synthetic organic pesticides which includes the herbicide paraquat and diquat.

black flies: True flies in the order Diptera whose larvae live in fast-flowing waters; females bite and draw blood.

blanket application [see broadcast treatment]

bottom treatment: An application method that injects the pesticide into bottom water by connecting weighted brass pipes to hoses that extend from a boom on a spray boat.

broadcast treatment: Application of pesticide over an entire surface.

broad-spectrum herbicide [see nonselective]

buffer: Type of adjuvant used to lower the pH of water in the spray tank. Buffers tend to stabilize the pH at a relatively constant level.

buffer zone: An untreated strip of water near the shoreline; minimizes risk of drift.

byssus threads: Ligaments produced by certain mussel species that bind the organism to its substrate.

C

calcium carbonate ($CaCO3$): A dissolved inorganic compound that, when present in large amounts in water, may have application implications for certain copper-based algaecides.

calibration: The process of measuring and adjusting the amount of pesticide being applied through a nozzle, sprayer, or granular applicator over a given area.

carrier: The inert liquid or solid material in a pesticide product that serves as a delivery vehicle for the active ingredient.

carrying capacity: The population size of a given species that its environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment.

cell membrane disruptor: A pesticide whose mode of action destroys cell membranes, causing cell contents to leak out and tissues to desiccate. An example is diquat.

certified applicator: Any applicator who has satisfactorily completed the certification requirements for commercial applicator, limited commercial applicator, public applicator, or private applicator.

chelate [-d]: A chemical form in which the central metal ion forms two or more bonds to a chelating agent. Chelated forms of ions are very stable.

chemical control: Reduction of pest populations or prevention of pest injury by the use of pesticides.

chemical degradation: The breakdown of a pesticide by oxidation, reduction, hydrolysis, or other chemical means.

chemical name: The name given by scientists to the active ingredient(s) found in the formulated product. This complex name is derived from the chemical structure of the active ingredient.

chemoreceptor: A structure within an organism's cells that alerts it to the presence of certain chemical compounds and causes changes in the organism's metabolism and behavior.

chlorophyll: The pigment that makes photosynthesis possible and that makes plants green.

chlorosis: Yellowing of foliage.

chronic toxicity: The ability of a substance or mixture of substances to cause harmful effects over an extended period, usually upon repeated or continuous exposure sometimes lasting for the entire life of the exposed organism.

clay: Cohesive soil whose individual particles are not visible to the unaided human eye (less than 0.002 mm in diameter). When moist, clay can be molded into a ball that will not crumble.

commercial applicator: Any person or company who engages in the business of applying pesticides or operating a device for hire. A certified applicator (whether or not he or she is a private applicator with respect to some uses) who uses or supervises the use of any pesticide which is classified for restricted use for any purpose on any property other than as provided by the definition of "private applicator".

compatible: Chemical formulations that, when tank mixed, will not alter one another's characteristics or efficacy.

compatibility agent: An adjuvant that facilitates more uniform mixing of liquid fertilizer and pesticides, or the mixing of two or more pesticides in a tank mix with any liquid carrier.

competition: The interaction between organisms for space, nutrients, moisture, or light.

concentrated emulsion (EW): A liquid pesticide formulation that consists of a thick emulsion and a paste of active ingredient.

concentration: Amount of pesticide present in a mixture, by proportion.

concentration and exposure time relationship: efficacy is a relationship expressed as: efficacy=concentration × exposure time

contact herbicide: A herbicide that causes localized injury to plant tissue on contact, without necessarily being translocated within the plant. Often used in reference to a spray applied directly to the pest.

continuous pulse treatment: Low concentrations of chemicals are pulsed into waters to decrease mussel veliger settling.

continuous treatment: Low levels of chemicals are continually released into the water to prevent all veliger settling.

control valve: All valves other than the pressure regulator that regulate the flow of liquid.

copper compounds: Non-selective, contact algaecides and molluscicides that function as cell membrane disruptors.

corrosion: The disintegration of a material into its constituent parts, usually by oxidation. Materials used for pesticide application should resist corrosion.

cotyledon: The first leaf or pair of leaves that emerge from the embryo of a seed plant.

cross-resistance: A pest population which has become resistant to one pesticide also becomes resistant to other chemically related pesticides.

cultural control: Pest management practices that rely upon manipulation of the aquatic environment (e.g., drawdown).

cuticle: A thick waxy layer on the leaf that protects it from water loss and pathogen invasion.

D

delivery [see application rate]

dermal exposure: Exposure to a pesticide through the skin.

desiccation /dewatering: The process of drying out; a state of extreme dryness.

dicot: A plant that emerges from the seed with two cotyledons; broadleaved plants.

diluent: Anything used to dilute a pesticide.

diquat: A nonselective contact herbicide that functions as a membrane disruptor.

direct injection sprayer: A sprayer that precisely mixes the chemical with its carrier using a special pump, eliminating mixing and cleaning processes.

dissolved oxygen (DO): The measured level of oxygen in a water body, expressed as ppm. Most ponds have a DO of 10 ppm or less.

Drain, Clean, and Dry: A process used to prevent the spread of invasive species from boat traffic.

dredging: Any action, usually with a machine, that scrapes the bottom of a water body to remove sediment.

drift: The movement of airborne particles or vapors away from the intended target area.

dry flowable (DF): Formulation made of finely ground herbicide particles, compressed into granules that can be suspended readily in water for application.

dust (D): A finely ground, dry pesticide formulation containing a small amount of active ingredient and a large amount of inert carrier or diluent such as clay or talc.

E

economic threshold [see action threshold]

ecosystem: A functional unit consisting of all the living organisms (plants, animals, and microbes) in a given area, and all the non- living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size—a log, pond, field, forest, or the earth's biosphere—but it always functions as a whole unit. Ecosystems are commonly described according to the major type of vegetation, for example, forest ecosystem, old- growth ecosystem, or range ecosystem.

effective contact time (ECT): The contact time with the target pest that is required for a pesticide to be effective. Determined by each species' susceptibility to a particular pesticide.

efficacy: The effectiveness of a given pesticide or pest control method at controlling a particular pest species under a given set of conditions.

emersed or emergent: A plant that is rooted in the sediment, but grows upward and out of the water.

emulsifiable concentrate (EC): A concentrated pesticide formulation containing organic solvents and emulsifiers to facilitate mixing with water.

emulsifier: A substance that promotes the suspension of one liquid in another.

emulsion: Suspension of small droplets of one liquid in another. Usually an oil-based pesticide mixed in water.

endangered species: Animals, birds, fish, plants, or other living organisms threatened with extinction by human caused or natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.

Endangered Species Act (ESA): A federal law that makes it illegal to "take" or harm any animal listed as endangered by the United States Fish and Wildlife Service.

end of season treatment: A strategy used to treat adult mussels; chemical is applied at a rate high enough and long enough that 80–90% mortality is reached.

endothall: A contact herbicide with an unknown mode of action.

Environmental Protection Agency (EPA): Responsible for the protection of the environment in the U.S. including registration and regulation of pesticides.

epinasty: More rapid growth on the upper surface of a plant part (especially leaves), causing it to bend downward (twisting).

eradicate: To destroy an entire pest population in an area.

erect algae: Resemble vascular plants and grow from the sediment from holdfast structures.

eutrophication: An increase in the concentration of dissolved mineral nutrients that can cause over-production in the water body, leading to the depletion of dissolved oxygen and to fish and plant deaths.

exotic species [see introduced]

exposure: Occurs when a person comes into contact with a chemical in the environment. May involve oral ingestion, inhalation, or absorption through the skin or the mucus membranes of the eyes, nose, or mouth.

F

Federal Department of Transportation (DOT): regulates shipment of pesticides and other dangerous substances across state lines.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA): A federal law that instructs the EPA to regulate: 1) the registration of all pesticides used in the U.S., 2) the licensing of pesticide applicators, 3) registration of all pesticide products, 4) the storage, transportation, disposal, and recall of all pesticide products.

filamentous algae: Algal cells arranged in long hairs or filaments, either floating or attached to the substrate.

first aid: The first effort to help a victim of pesticide exposure.

flagella: A tail-like structure that protrudes from single-celled organisms, used for locomotion.

flowable (F): Formulation made of finely ground pesticide particles that are suspended in a liquid, which is then diluted with water for application.

fluridone: A translocated, selective pigment inhibitor.

foliar: Refers to a plant's foliage or leaves; e.g., a foliar application applies herbicide directly to the leaves.

formulation: Pesticide product as sold, usually a mixture of active and other (inert) ingredients.

fragmentation: a common type of vegetative reproduction in plants.

free-floating: A plant that is not attached to the substrate but floats on the water surface.

G

gallons per minute (GPM) or gallons per hour (GPH): a measure of liquid moved by a pump.

gametes: Cells of an organism that fuse with another cell during sexual reproduction; e.g., eggs and sperm.

gel: Semi-liquid emulsifiable concentrates that are used with water-soluble packaging.

general use pesticide (GUP): A pesticide which can be purchased and used by the general public without undue hazards to the applicator and the environment, as long as the instructions on the label are followed carefully.

germinate: The process that occurs when the first leaves and roots emerge from the seed.

glyphosate: A non-selective, translocated amino acid synthesis inhibitor; a very commonly used herbicide.

granular (G): A dry formulation of pesticide and other components in which the active ingredient is impregnated on discrete particles, such as clay or ground corncobs. They are applied in the dry form.

groundwater: The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs.

growth regulator herbicides: Used for controlling or modifying growth processes without appreciable phytotoxic effect at the dosage applied. Examples include 2,4-D and triclopyr.

H

habitat alteration [see cultural control]

hazard: The probability that injury or detrimental effects will result if a substance, mixture of substances, or a process involving substances is not used properly. Hazard is a function of toxicity and exposure.

hazardous waste: A substance having properties capable of having adverse affects on the health or safety of individuals.

herbaceous: a fleshy plant with no little or no woody material.

herbicide: A chemical that kills or suppresses the growth of weeds by acting on the plant's physiology.

herbivorous: feeding on plants; plant-eating.

hopper: Part of a granular applicator that holds the dry pesticide.

host: The living plant or animal that serves as food for a predator, parasite, or pathogen.

hydraulic sprayer: A machine which applies pesticides by the pressure created by forcing liquid through a narrow opening.

hydrosoil: The water body's bottom sediments.

I

imidazolinones: A translocated herbicide that acts as an amino acid synthesis inhibitor, selective against broadleaf weeds.

incompatible: Not capable of being mixed or used together. In the case of pesticides, the effectiveness of one or more is reduced, or they cause injury to plants or animals.

inert ingredient: That part of a formulation without toxic or killing properties. Also referred to as "other ingredients."

inhalation exposure: Exposure to a pesticide through the lungs.

insect: Members of the class Insecta; characterized by a hard exoskeleton, three body sections, six legs, a single pair of antennae, and compound eyes. Common examples of insects include grasshoppers, true bugs, beetles, butterflies, moths, flies, bees, and wasps.

insecticide: A chemical that kills or suppresses insect populations.

Integrated Pest Management (IPM): An approach to the management of pests in which all available control options, including physical, chemical, and biological controls, are evaluated and integrated into a unified program.

introduced: Plants that did not evolve in the area that they presently inhabit.

invasive: A species whose introduction causes or is likely to cause economic harm, environmental harm, or harm to human health.

invert emulsion: An emulsion in which water is dispersed in oil rather than oil in water. Usually has a mayonnaise-like consistency.

invertebrate: An animal without a spine. 95% of all animal species.

K

KCl [see potassium chloride]

KMnO4 [see potassium permanganate]

L

label: All written, printed, or graphic matter on or attached to the pesticide product, or the immediate container thereof, and the outside container or wrapper to the retail package of the pesticide product.

labeling: All information and other written, printed, or graphic matter upon the pesticide product or device or any of its accompanying containers or wrappers to which reference is made on the label or in supplemental literature accompanying the pesticide product or device.

larva, plural -ae: An immature insect. Refers to the feeding stages of insects with complete metamorphosis like grubs, caterpillars, and maggots.

LC50: Measure of toxicity expressed in parts per million. The lethal concentration of a pesticide in water or air that will kill 50% of test animals within a designated period.

LD50: Measure of toxicity expressed in milligrams per kilogram of body weight. The lethal dose of a pesticide that will kill 50% of test animals within a designated period. Standard measurements include the acute oral LD50 and the acute dermal LD50. The lower the LD50, the more toxic the compound.

leaching: The downward movement of a substance in solution through the soil.

leech: A carnivorous or bloodsucking aquatic or terrestrial worm typically having a sucker at each end.

life cycle: Series of stages an organism passes through during its lifetime.

low-pressure sprayer: A machine which can deliver low to moderate volumes of pesticide at pressures of 0–60 psi.

M

marmot: A large ground squirrel adapted to digging.

mechanical control: [see physical control]

metabolism, -ize: The complete set of chemical reactions that take place in a cell and enable an organism to live. Turning one compound or molecule into another. Photosynthesis is an example of metabolism.

mesotrophic: Describes a lake with an intermediate level of nutrients and productivity, as opposed to a eutrophic lake [see eutrophication].

microbial degradation: Breakdown of a chemical by microorganisms.

microencapsulated pesticide: Pesticide active ingredients that are contained in a shell. The shell extends the residual life of the pesticide by slowing the release of the active ingredients.

mode of action: Manner by which pesticides kill or inhibit an organism. Sometimes referred to as the mechanism of toxicity.

molluscicide: A chemical used to control mollusks.

mollusks: A large group of land and water animals including snails and slugs.

monocot: A plant that emerges from the seed with one cotyledon, e.g., grasses.

multiple resistance: A pest that can tolerate insecticides from different classes of compounds having different modes of action.

muskrat: A medium-sized, semi-aquatic rodent.

N

native: An organism that has developed and occurs naturally in the area where it is found.

natural enemies: Parasites, predators, or pathogens that prey on a particular pest.

necrosis: Localized death of a certain area of living plant tissue.

neutralization: Rapid pesticide degradation into an inactive form, usually induced by the applicator.

non-oxidizing compound: A type of molluscicide used for disinfection.

nonselective herbicide: A chemical that is generally toxic to plants without regard to species. Toxicity may be a function of dosage, method of application, etc.

nontarget: Any site or organism other than the site or pest at which a pest control method is being directed.

noxious weed: Any plant designated by a federal, state, or county government as injurious to public health, agriculture, recreation, wildlife or property.

nozzle: The part of the sprayer that converts liquids into droplets with a predetermined spray pattern. Proper nozzle selection and maintenance is essential for uniform, thorough, and safe applications.

nutrient loading: The enrichment of surface waters with elements such as nitrogen and phosphorus, generally from surface runoff.

O

oral exposure: Exposure to pesticides through the mouth.

organic matter: Residues of dead plants or animals in various states of decomposition in the soil.

orifice: The opening or hole in a nozzle through which liquid material is forced out and broken up into a spray.

otolith: A specific bone inside a fish's head (an "ear-bone"); accretion of calcium carbonate in these bones varies with growth and can be used to determine fish age.

oxidizing compound: A type of molluscicide used for preventive treatments.

P

parasite: An organism that lives in or on another living organism and is detrimental to . A parasite may or may not kill its host.

parasitoid: A type of parasite that develops as larvae in or on a host insect from eggs laid on, in, or near the host.

partial drawdown: Decreasing the water level in a lake or pond to concentrate fish species and dry out shallow areas.

parts per million (ppm): A measure of pesticide concentration. One ppm is one unit of pesticide per every million units of carrier (water, oil, food, etc).

particle drift: Occurs when sprays are carried away from the application area by air movements.

pathogen: Any disease-producing organism.

perennial: A plant that lives from year to year, for three years or more under normal growing conditions.

periodic treatment: A control strategy for adult mussels that targets them on a regular basis throughout the season.

persistence: The length of time a pesticide remains active after application, giving continued protection against the pest.

personal protective equipment (PPE): Devices and apparel worn to protect the body from exposure to pesticides or pesticide residues.

pest: An organism that interferes with human activities, property, or health, or is otherwise objectionable.

pesticide: Any substance or mixture of substances that are intended for preventing, destroying, repelling, or mitigating any pest. Also, any substance or mixture intended for use as a plant regulator, defoliant, or desiccant.

pesticide resistance: An organism's genetically inherited ability to withstand doses of pesticide which would kill individuals from species whose ancestors had not been exposed to the pesticide.

petiole: The stalk of a leaf that attaches to the stem.

pH: A value expressing the acidity or alkalinity of a solution on a scale of 1 to 14; the neutral point is 7.0. Below 7 is acid and above 7 is alkaline (basic).

photic zone: The part of a body of water in which light intensity is sufficient to support plant growth; extends to the point that light intensity is 1% of sunlight.

photodegradation: Breakdown of chemicals by the action of light.

photoperiod: The normal duration of natural daylight experienced by an organism; day length.

photosynthesis: The manufacture of carbohydrates and release of oxygen from carbon dioxide, mediated by chlorophyll in the presence of sunlight.

physical control: Control of pests by physical means such as weeding, heat, cold, sound waves, etc.

physical incompatibility: Incompatibility that results in the formation of precipitates or layers of pesticides in the mixing or application equipment.

physiology: The chemical processes, such as respiration and photosynthesis, through which an organism maintains itself and supports its growth.

phytoplankton: Another term for free-floating or planktonic algae.

phytotoxicity: A measure of the level of injury or toxicity of a pesticide to plants.

pigging: Process of mussel removal that involves flushing water lines with small plugs, or "pigs".

pigment inhibitor: A herbicide whose mode of action causes chlorophyll in plants to be destroyed. Fluridone is an example.

piscicide: Any substance intended for

preventing, destroying, or repelling fish.

planimeter: A tool that can be used to measure the area of an irregular shape by tracing its perimeter.

planktonic algae: Individual algae cells that are suspended in the water or form a film on the surface.

Plant Protection Act (PPA): A federal law that gives the U.S. Department of Agriculture the power to designate plants as noxious weeds and to prevent the entry of these plants into the country.

pollinator: An insect that transfers pollen from one flower to another, assisting in plant reproduction.

polymer [see invert emulsion]

pond scum: a mass of filamentous algae forming a green scum on the surface of ponds and other such bodies of water.

post-emergence: Application of a herbicide after emergence of the specified weed or plant.

potassium chloride (KCl): An effective molluscicide that works on both adults and veligers; used in the Drain, Clean, and Dry strategy.

potassium permanganate (KMnO4): A strong oxidizing agent that has the ability to kill living organisms.

precipitate: To settle out of solution, i.e., iron precipitates when it binds with oxygen.

predator: An animal used in a biological pest control program that attacks and kills pests.

pre-emergence: Application of a herbicide to the soil prior to the emergence of the specified weed or plant.

pressure gauge: A device that indicates pressure differential above or below atmospheric pressure.

pressure regulator: Device that controls the pressure of spray material delivered by nozzles.

prevention: Keeping a pest from becoming a problem through cultural or biological means.

private applicator: an EPA certified applicator who uses or supervises the use of any pesticides which is classified for restricted use for purposes of producing any agricultural commodity on property owned or rented by him or his employer or (if applied without compensation other than trading of personal services between producers of agricultural commodities) on the property of another person.

pseudofeces: Uneaten food bound with mucus that is secreted by mussels and accumulates in their colonies.

Q

quarantine: Official confinement of exotic pests not previously found in the U.S., pests which are known to have caused high levels of economic damage in the past, or pests known to cause high levels of economic damage under similar conditions of climate and natural habitat in other areas, which are likely to be introduced into an area by the importation of plants or plant parts, whether living or dead, domestic animals, or other objects.

R

rangefinder: A device that measures distance from the observer to a target.

rate: [see application rate]

re-treatment: Repeat treatment more than once in a season; generally required for good control of algae and some other aquatic plants.

ready-to-use formulation (RTU): No further dilution of the formulation is required before application.

record keeping: Detailed list of pesticide applications performed by applicators. Required by many states.

repellent: A substance used to drive away insects or other undesirable organisms.

residue: Pesticide that remains on or in raw farm products or processed foods.

residual: Refers to the property of a substance (pesticides are one example) that allows it to remain in an area for an extended period.

resistance, resistant: [see pesticide resistance]

restricted entry intervals (REI): The mandatory period of time between application of a chemical and entry to the treated area.

restricted use pesticide (RUP): A pesticide which is designated as such by the EPA because it is felt that it may generally cause, without additional regulatory restrictions, unreasonable adverse effects on the environment, including injury to the applicator. A restricted use pesticide may be used only by, or under the direct supervision of, a certified applicator.

rhizome: A specialized horizontal stem that grows below ground or just at the soil surface. They are capable of sending out roots and leafy shoots.

rinsate: Rinse water from a pesticide tank cleaning.

rooted floating: A plant that is rooted to the substrate with leaves that float on the surface of the water.

rosette: Compact cluster of leaves radiating at ground level, often in a circle.

rotenone: A type of piscicide with low selectivity, low persistence, and low toxicity to aquatic animals other than fish.

rotovation: uses underwater rototiller-like blades to uproot plants.

RPM: revolution per minute

S

Safety Data Sheet (SDS): Formerly known as the Material Safety Data Sheet (MSDS). A document required for each hazardous chemical including pesticides by the Occupational Health and Safety Act. It contains health and safety data as well as physical properties pertinent to the chemical which will aid in an emergency situation. An SDS can be obtained through the distributor or the manufacturer of the pesticide.

sand: Soil particles ranging from 0.05 to 2.0 mm in diameter. Individual particles are visible to the unaided human eye.

schistosomiasis: Also known as swimmers' itch; irritation of the skin caused by the larvae of the swimming worm Schistosoma.

scouting: Routine observation of aquatic environments to record pertinent information on desirable and undesirable species.

Secchi depth: The depth of water clarity, as measured with a Secchi disk.

Secchi disk: A disk 8 inches in diameter with alternating black and white sections, used to measure water clarity.

secondary poisoning: poisoning that can result when one organism comes into contact with or ingest another organism that has poison in its system.

seine: A net attached to two wooden uprights on each end; used to cull fish from a water body.

selective pesticide: A pesticide that is more toxic to some kinds of plants and animals than to others.

selectivity: The degree to which a pesticide is more toxic to specific organisms.

shared mechanisms of toxicity: The similar patterns of illness caused by exposure to one family of pesticides.

shoreline alteration: A cultural control method that works to prevent erosion and unwanted weed establishment.

sign of pesticide poisoning: An observable consequence of pesticide poisoning such as vomiting or sweating.

silt: Noncohesive soil whose individual particles are not visible to the unaided human eye (0.002 to 0.05 mm). Silt will crumble when rolled into a ball.

soil application: A pesticide applied primarily to the soil surface rather than to vegetation.

soil texture: The relative proportion of sand, silt, and clay in the soil.

solubility: The amount of a substance that will dissolve in a given amount of liquid.

soluble powder (SP): A powder formulation that dissolves and forms a solution in water.

solution: [see true liquid solution]

species: A group of similar looking organisms that can and do reproduce with one another and which cannot breed successfully with other species. Abbreviated "spp."

spot treatment: Application of a pesticide over small continuous restricted area(s) of a whole unit; i.e., treatment of spots or patches of weeds within a larger area.

spray drift: [see drift]

spraying vegetation to wet: All foliage and stems are thoroughly covered.

sticker: An adjuvant that increases the ability of a pesticide to stick to treated plant surfaces.

stolon: A specialized horizontal stem that grows above ground. Runners or stems develop roots and shoots at the tip or nodes.

strainer: A screen used to prevent scales, rust flakes, and other foreign material from plugging nozzles or other working parts of a sprayer.

stunting: Growth that is significantly slower than normal.

sublethal: An effect of a pesticide that does not kill an organism but reduces the organism's ability to reproduce and survive.

submersed: A plant that grows entirely below the surface of the water.

substrate: The soil, rock, or hydrosoil that an aquatic plant roots to for support.

suppression: Reduction of a pest population, but not elimination.

surface water: All water naturally open to the atmosphere (rivers, streams, creeks, brooks, reservoirs, ponds, lakes, etc.), whether natural or artificial.

surfactant: A surface-active agent that changes the surface tension of liquids.

susceptible: A pest that is capable of being injured by a pesticide.

suspension: A liquid or gas in which very fine solid particles are dispersed, but not dissolved. Example: wettable powder in water.

suspension concentrate (SC): A liquid pesticide formulation consisting of finely ground particles in a liquid base; forms a suspension when diluted. Also referred to as a flowable (F).

swath width: The horizontal distance covered by one pass of spraying equipment.

swimmer's itch: [see schistosomiasis]

symptom of pesticide poisoning: An indication that poisoning has occurred that can only be observed by the poisoned person; i.e., nausea or headache.

synergist: A substance added to a pesticide to enhance its activity.

systemic pesticide: A pesticide that is absorbed and translocated throughout the plant or animal.

T

tank-mix: The mixture of two or more compatible pesticides in a spray tank in order to apply them simultaneously.

tank: A major component of a sprayer that holds the liquid used in pesticide application.

taproot: Main root of the plant growing straight downward by the stem.

target pest: The organism that a pesticide application intends to control.

temperature inversion: A condition in which air above an area is warmer than air near the ground. This warm air forms a cap that may cause a pesticide vapor or droplets to collect and concentrate.

thermal stratification: Layering of lake waters that occurs primarily during warmer months; a warm layer of water "floats" atop a cooler, denser layer of water.

thermocline: In thermally stratified lakes, the boundary between the warm and cool water layers.

tolerance: The maximum concentration of pesticide allowed on/in a food item.

tolerant: A plant species that normally survives herbicide treatment without injury.

toxicity: The degree to which a substance or mixture of substances can harm humans or animals.

translocated: A pesticide that is absorbed into and moved through the organism's tissue.

triple rinse procedure: Rinsing a pesticide container three times in order to ensure that it is legally empty.

true liquid solution (L): When the active ingredient is mixed with water, the water remains clear.

turbidity: A measure of the amount of particles suspended in water.

turion: A special overwintering bud produced by some aquatic weeds.

U

ultraviolet (UV) light treatment: A treatment used to control mussel veligers.

V

vapor drift: The movement of chemical vapors from the area of application. Some herbicides, when applied at normal rates and normal temperatures, have a sufficiently high vapor pressure that causes them to change into vapor form which may cause serious injury to susceptible plants away from the site of application. Note: Vapor injury and injury from spray drift are often difficult to distinguish.

vector: An organism that carries and transmits a disease.

veliger: The microscopic larval form of mussels.

venturi rig: A boat set-up used for deep water treatments in large lakes; involves attaching a boat-bailer to the outboard motor and siphoning chemical into the water from an onboard tank.

vertebrate: An animal with a spine.

viscosity: A measure of a formulation's thickness and its resistance to flow.

volatilization: The chemical process of passing from a liquid state to a vapor or gas, such as when vapors are released from a liquid pesticide.

volume treatment: A treatment that is calibrated and executed according to the whole or partial volume of the water body.

volume/volume solution: A pesticide recommendation expressed as a given amount of product in a specified volume of water.

W

water clarity: The amount of dissolved solids present in a water body. Measured by the Secchi depth.

water dispersible granules (WDG): A pesticide formulation in which finely-divided powders are formulated into concentrated, dustless granules which form a suspension in water.

water hardness: A measure of the dissolved elements calcium, magnesium, iron, and strontium.

watershed: The entire geographical area drained by a river and its tributaries; an area characterized by all runoff being conveyed to the same outlet.

water soluble packets (WSP): A packaged pesticide formulation that contains a preweighed amount of formulation in a bag that will dissolve in the spray tank.

water use restriction: A legal requirement that may restrict swimming, fishing, drinking, or otherwise using water for a specific length of time after a pesticide treatment.

weed: A plant that grows where it is unwanted.

wetland: An area that is saturated by surface or ground water with vegetation adapted to life under those conditions; includes swamps, bogs, fens, marshes, and estuaries.

wettable powder (WP): A dry pesticide formulation, usually mixed with water for application. Does not dissolve in water, but forms a suspension.

winter drawdown: Decreasing the water level in the lake or pond in order to expose shallow areas to freezing and drying conditions.

wye: A Y-shaped connector used in liquid systems.

Z

zoospores: A cell, usually propelled by flagella, used for asexual reproduction.

zygote: The initial cell formed when two cells fuse during sexual reproduction.

ILLUSTRATIONS

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