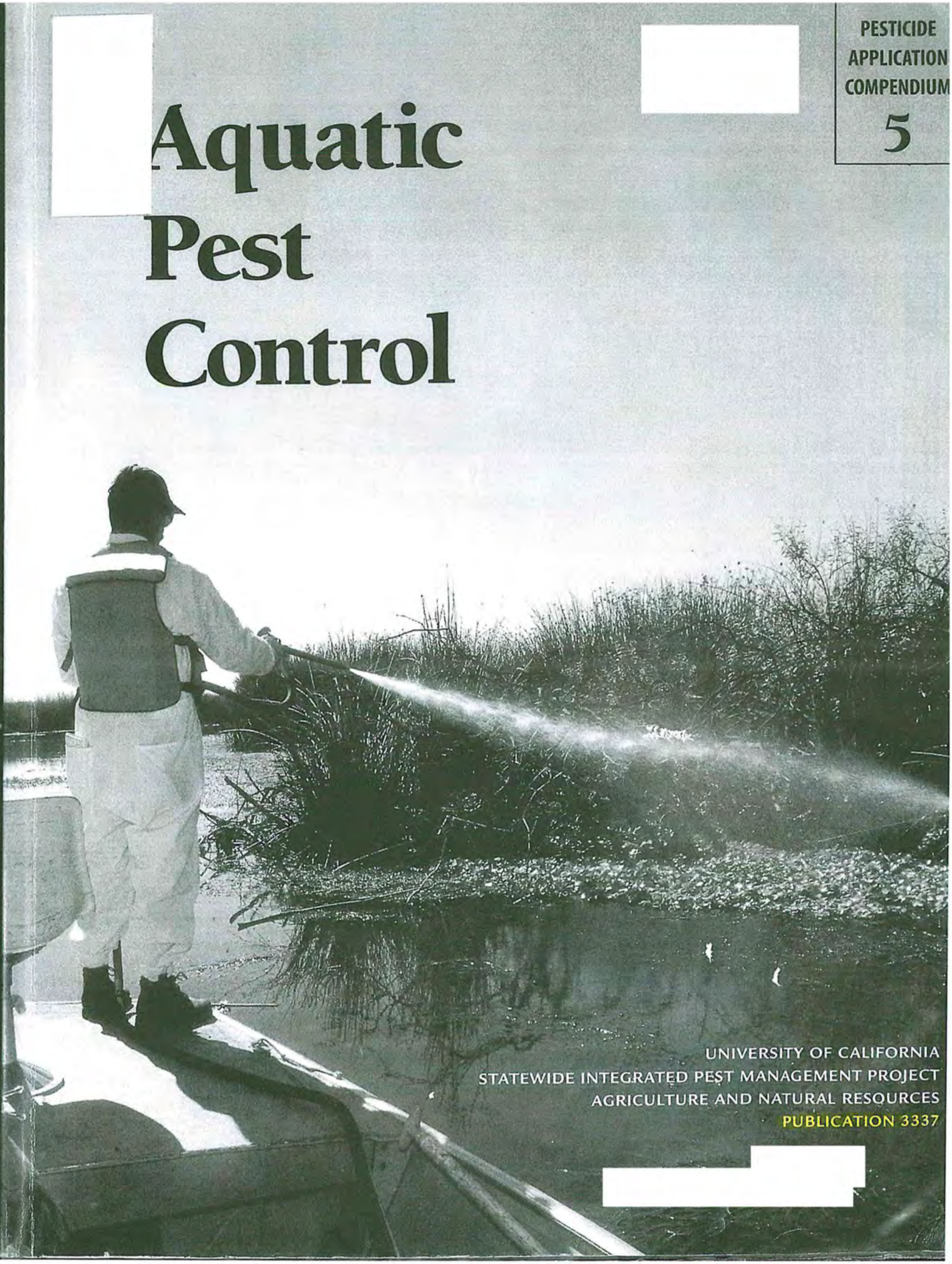
PESTICIDE APPLICATION COMPENDIUM

5

Aquatic Pest Control



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STATEWIDE INTEGRATED PEST MANAGEMENT PROJECT
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APPLICATION
COMPENDIUM
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Statewide Integrated Pest Management Project
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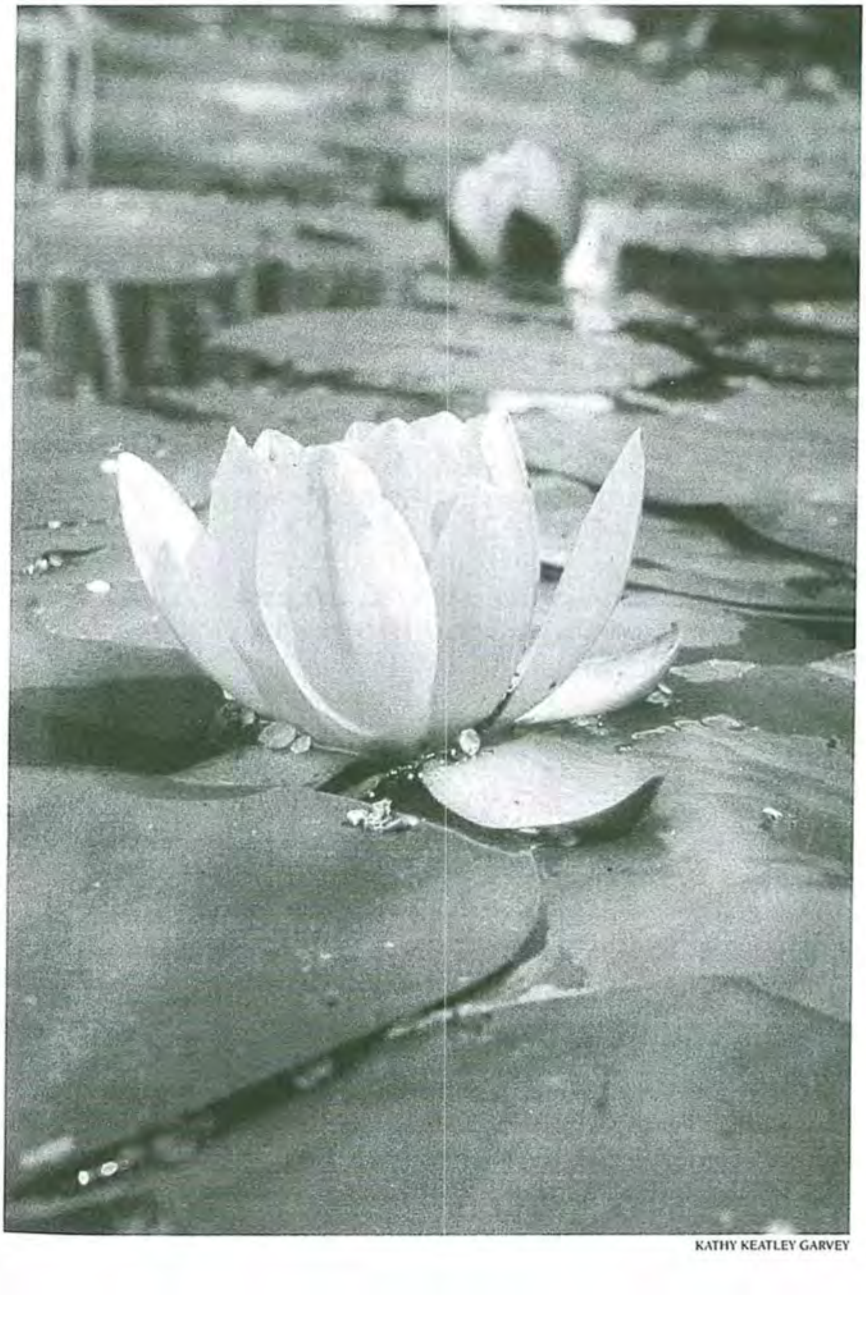

KATHY KEATLEY GARVEY

Waterlilies have the ability to take over a shallow pond.

THIS MANUAL WILL HELP YOU prepare for the California Department of Pesticide Regulation *Qualified Applicator Certificate (QAC)* or *Qualified Applicator License (QAL)* examinations in the Aquatic Pest Control category. Federal and state laws require that you pass one of these exams in order to apply or supervise the application and handling of restricted-use pesticides in aquatic areas. These aquatic pest control examinations are based on the knowledge expectations listed in Sidebar 1. These knowledge expectations are the basis for this manual and the additional study materials described below.

USING THIS MANUAL

Besides its use as a study guide, the information in this manual will help you make effective aquatic pest management decisions that will reduce hazards to yourself, other people, and the environment. Before applying pesticides to aquatic environments, consult this book for information on pests, pest management, and pesticide uses.

The sidebars and tables that are found throughout this manual include important and useful information to help you understand the unique characteristics of aquatic environments and how to use pesticides in these areas safely.

If you are preparing for the Department of Pesticide Regulation (DPR) examinations, the following sections describe what you need to know and where to find that information in this book and in other study materials.

Pests and Pest Management. As a certified pesticide handler, you must recognize common pests and the damage caused by them. You should also understand the concepts of pest management, including principles of *integrated pest management.* (See chapters 1, 2, 3, and 4 in this manual and chapters 1, 2, and 8 in *The Safe and Effective Use of Pesticides, Second Edition.*)

The Pesticide Label. You must demonstrate that you can read and understand pesticide labels and associated labeling information. This includes recognizing restrictions on using certain pesticides, understanding worker safety and protection requirements, and recognizing and understanding how to protect environmentally sensitive areas. (See chapter 5 in this manual and chapters 3, 4, and 6 in *The Safe and Effective Use of Pesticides, Second Edition.*)

Mixing and Applying Pesticides. You need to know how to prepare proper concentrations of pesticides for use under particular circumstances. You also must be able to select application equipment and correctly calibrate this equipment. You will be required to demonstrate your ability to avoid offsite movement of pesticides during application. (See chapters 5 and 6 in this manual and chapters 6, 8, 9, and 10 in *The Safe and Effective Use of Pesticides, Second Edition.*)

Laws and Regulations Affecting Pesticide Use. You must recognize

SIDEBAR 1

Certification Standards for People Using Restricted-Use Pesticides

People who apply restricted-use pesticides in aquatic areas must understand

- ☐ pesticide labels and labeling, including legal implications, warnings, symbols, and other information commonly appearing on pesticide labels
- ☐ the meaning of the term "restricted-use"
- ☐ safety guidelines for pesticide use, including acute and chronic toxicity risks, exposure hazards, and how risk is determined by exposure and specific pesticide hazards
- ☐ environmental risk factors, including climatic influences on pesticide drift and runoff and how terrain, soil, and subsoil, as well as pesticide characteristics, influence the contamination of surface water and groundwater
- ☐ how to recognize sensitive areas and organisms affected by pesticide applications, drift, and runoff
- ☐ how to protect endangered and threatened species
- ☐ how to prevent and clean up spills
- ☐ how to recognize symptoms of acute toxicity and practical treatment for pesticide exposure
- ☐ the precautions to prevent injury to applicators and other people in or near treated areas
- ☐ the necessity for and use of personal protective equipment, worker warnings, and restricted-entry restrictions
- ☐ how to safely transport, store, mix, handle, apply, and dispose of pesticides and empty containers
- ☐ the principles of pest identification and biology, and how to recognize the damage or problems caused by pests
- ☐ the types of pesticides, formulations, and adjuvants, as well as factors affecting pesticide effectiveness
- ☐ how to select the correct formulations and application methods for the site and pest
- ☐ the characteristics and uses of the equipment required for application, proper care and maintenance of equipment, and how to select appropriate equipment for the application site and pest
- ☐ calibration techniques and how to make dilutions in accordance with label directions
- ☐ how to determine the area or volume to be treated and the amount of pesticide to be applied and how to adjust application equipment to meet desired calculations for pesticide output
- ☐ federal and state laws and regulations relating to pesticide applicators and applications; applicator responsibilities for pesticide use consistent with label directions; supervision requirements for noncertified employees assigned to handle restricted-use pesticides, and applicator liability and penalties

environmentally sensitive areas and protect these from pesticide exposure. You must also show that you know how to protect groundwater and endangered species. You must be familiar with current regulatory changes and know how to locate regulatory information. (See chapter 5 in this manual and chapters 4, 5, 6, and 8 in *The Safe and Effective Use of Pesticides, Second Edition;* also read the *Laws and Regulations Study Guide* available from the Department of Pesticide Regulation.)

Recognizing and Preventing Pesticide Poisoning. You must recognize common symptoms of pesticide poisoning and demonstrate that you know how to protect yourself and others from exposure by using personal protective equipment. You also need to understand the first aid procedures for pesticide exposure. (See chapter 5 in this manual and chapters 5, 6, and 7 in *The Safe and Effective Use of Pesticides, Second Edition.*)

Protecting the Environment. You must recognize the negative impact of pesticides on nontarget organisms. You need to understand how environmental contamination occurs and how to prevent this. You must be familiar with endangered species and how to protect them when making pesticide applications. You need to know how to properly handle, store, and dispose of leftover pesticides, pesticide mixtures, and empty containers. (See chapter 5 in this manual and chapters 5, 6, and 8 in *The Safe and Effective Use of Pesticides, Second Edition.*)

Pesticide Emergencies. You need to know where to get first aid information for pesticide exposure and how to administer first aid to an exposure victim. You must understand the procedures for dealing with pesticide spills and fires. You have to recognize problems associated with misapplication of pesticides and what to do in case it happens. (See chapter 5 in this manual and chapters 5, 6, and 7 in *The Safe and Effective Use of Pesticides, Second Edition.*)

Using the Review Questions

At the end of each chapter are several review questions to test your grasp of the information presented in that chapter. These questions are written in the same format as the questions on the DPR examinations. If you have had some training and experience with handling pesticides, you will probably be able to answer many of the questions without studying the information in the chapter.

Begin your study of each chapter by reading through the review questions. Make notes of the subject material you do not fully understand. Then, review the chapter to locate the sections that deal with that information. Read those sections carefully before you review the rest of the chapter.

When you finish studying the chapter, answer each of the review questions. Check your answers against the correct answers on page 145. If you missed any of the questions, go back and reread the appropriate sections of the chapter that cover that information.

Other Useful Pesticide Resources

This and the other volumes in the Pesticide Application Compendium series are useful references for anyone involved in making pesticide use decisions. Books in this series are also helpful instructional guides if you are training people to use pesticides properly and safely. Besides this text, there are three important sources you

SIDEBAR 2

Types of Aquatic Environments

Aquatic environments that may require pest control efforts include

- ☐ aquaculture: fish ponds, fish hatcheries, and other types of fish production facilities
- ☐ agricultural reservoirs: canals, levees, irrigation channels, and frost-control storage ponds
- ☐ municipal water supplies and drinking water reservoirs
- ☐ recreational waters: rivers, lakes, ponds, streams, and creeks that are used for fishing, hunting, swimming, boating, and other aquatic sports
- ☐ livestock watering ponds
- ☐ ornamental ponds: golf courses, parks, and businesses
- ☐ wildlife preserve ponds or waterways
- ☐ natural marshes, wetlands, and deltas

JACK KELLY CLARK

FIGURE I-1.

Ditches that collect runoff may need weed control.

should rely on for information regarding pesticides and pest management in aquatic areas.

USDA Agricultural Research Service (ARS). The USDA-ARS maintains an Exotic and Invasive Weeds research laboratory on the UC Davis campus. Specialists in this laboratory are experts in identification and management practices for aquatic weeds and algae. These specialists are an important resource for the public as well as University of California specialists and state regulatory agencies.

County Agricultural Commissioners. County agricultural commissioners (CACs) are regulatory officials of the California Department of Pesticide Regulation. Their offices throughout the state have the responsibility, among other functions, for issuing permits for restricted-use pesticides; monitoring pesticide use, storage, and disposal; and enforcing pesticide laws and regulations. Agricultural commissioners' offices provide local information on pesticide use, storage, transportation, disposal, and hazards. Contact your local CAC office if there is any pesticide emergency.

The University of California. Through its Cooperative Extension program, the University of California maintains offices in most counties of the state. Specialists (farm advisors) who staff these offices are able to provide pest identification, pest management, and pesticide use information for home, structural, agricultural, livestock and poultry, rangeland, wildlife, turf and landscape, forest, and aquatic areas. Farm advisors work closely with other University of California researchers and specialists.

JACK KELLY CLARK

FIGURE 1-2.

Exotic plants, such as this mat of waterhyacinth, can crowd out native vegetation.

THE AQUATIC ENVIRONMENT

As an aquatic pest manager, you must understand the unique characteristics of aquatic settings. If you become familiar with the organisms that live there and understand their life stages, significance, and interactions, it will help you develop successful strategies for managing aquatic pests.

The state of California has unique and diverse aquatic environments. These include marshes where fish and wildlife species thrive; irrigation canals used to transport water to farms; ditches that collect runoff (Figure 1-1); and golf course ponds that can be both functional and aesthetic. An aquatic site may have a specific use, such as a fish hatchery, or serve multiple purposes, such as a reservoir that is used for fishing, boating, flood control, and drinking-water storage. Sidebar 2 lists some of the many types of aquatic environments found in California.

Several factors within an aquatic environment may favor pest infestations. Also, changes in environmental conditions or management practices can disrupt natural balances and encourage the buildup of specific pests. Certain serious pests, once established, may interfere with the economic, environmental, or recreational uses of a body of water. Such pests may also create health or safety hazards.

Weeds are the most common aquatic pests. These weeds might be native plants that begin to grow excessively due to changes in the environment, or they can be non-native plants that compete with native vegetation (Figure 1-2). Other aquatic pests include invertebrates such as insects, crabs, clams, mussels, or snails. Under certain circumstances, vertebrates such as fish and birds and some mammals that live in or near water become pests. In addition, bodies of water can harbor microorganisms such as viruses, bacteria, and parasites that cause illnesses in animals and people.

Regulating Aquatic Environments

Many aquatic environments in California are highly regulated by a complex network of federal, state, and local agencies. Regulations often restrict uses and mandate the preservation of aquatic areas. Some of these laws specifically address pesticides.

SIDEBAR 3

Protected Animals in the Aquatic Environment

Federal and state laws protect endangered and threatened animals. Examples of animals protected in California include

Crayfish

- ☐ shasta crayfish *(Pacifastacus fortis)*

Fairy Shrimp

- ☐ conservancy fairy shrimp *(Branchinecta conservatio)*
- ☐ longhorn fairy shrimp *(Branchinecta longiantenna)*
- ☐ riverside fairy shrimp *(Streptocephalus woottoni)*
- ☐ vernal pool fairy shrimp *(Branchinecta lynchi)*

Salamanders

- ☐ desert slender salamander *(Batrachoseps aridus)*
- ☐ Santa Cruz long-toed salamander *(Ambystoma macrodactylum croceum)*
- ☐ tiger salamander *(Ambystoma tigrinum)*

Fish

- ☐ delta smelt *(Hypomesus transpacificus)*
- ☐ Lahontan cutthroat trout *(Oncorhynchus clarkii henshawi)*
- ☐ little Kern golden trout *(Oncorhynchus aguabonita whitei)*
- ☐ Paiute cutthroat trout *(Oncorhynchus clarkii seleniris)*
- ☐ Sacramento splittail *(Pogonichthys macrolepidotus)*

Other regulations protect water and air quality, wildlife, plants, and endangered or threatened species. Sidebar 3 lists some of the protected animal species in California's aquatic environments. Some of the endangered aquatic plants are listed in Sidebar 4.

The State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards (RWQCBs) have authority to protect water quality and enforce water-quality control programs. DPR works with these boards to ensure that pesticides registered in California are used in ways that protect water quality while providing effective, environmentally sound pest management.

DPR has the primary responsibility for regulating all aspects of pesticide sales and uses to protect public health and the environment. The county agricultural commissioners and DPR together enforce pesticide regulations in California.

SIDEBAR 4

Some Endangered Aquatic Plant Species in California

- ☐ Chorro Creek bog thistle *(Cirsium fontinale obispoense)*
- ☐ Gambel's watercress *(Rorippa gambelli)*
- ☐ marsh sandwort *(Arenaria paludicola)*
- ☐ Mason's lilaeopsis *(Lilaeopsis masonii)*
- ☐ salt marsh bird's beak *(Cordylanthus maritimus* ssp. *maritimus)*

1 Aquatic Weeds

JACK KELLY CLARK

Aquatic weeds clog waterways and shade out desirable plants.

MANY PLANTS ARE adapted to life in or near water. Most of

such as those listed in Sidebar 5.

The federal government classifies fewer than 20 of the known 700 aquatic plants as *noxious weeds.* Regulations prohibit the cultivation, propagation, transportation, or sale of these plants. Table 1-1 lists some of the world's most troublesome aquatic weeds. Sidebar 6 and Figure 1-1 describe some of the problems caused by aquatic weeds.

TYPES OF AQUATIC WEEDS

Weed specialists commonly catego-

ic weeds into four groups based on their distinctive structures and growth patterns. These categories are algae, emersed weeds, submersed weeds, and free-floating weeds (Figure 1-2).

Algae

There are 17,000 species of algae—primitive plants without true roots, leaves, or flowers. Algae are categorized as planktonic (free floating), filamen-

SIDEBAR 5

Benefits of Aquatic Plants

Most aquatic plants are beneficial because they

- provide food for organisms, including fish, birds, and mammals
- produce oxygen for fish and other aquatic animals
- provide habitat for numerous invertebrates and cover for fish
- stabilize shorelines by reducing erosion
- absorb water pollutants
- trap silt particles during treatment of sewage-polluted water
- provide nesting sites for birds
- improve the appearance of a body of water

TABLE 1-1.

Prevalent Species in California Considered to Be among the World's Most Troublesome Aquatic Weeds.

COMMON NAME	SCIENTIFIC NAME
EMERSED WEEDS	
alligatorweed	*Alternanthera philoxeroides*
barnyardgrass	*Echinochloa crus-galli**
giant reed	*Arundo donax**
purple loosestrife	*Lythrum salicaria*
cattail	*Typha* spp.
SUBMERSED WEEDS	
coontail	*Ceratophyllum demersum*
egeria	*Egeria densa*
common elodea	*Elodea canadensis*
Eurasian watermilfoil	*Myriophyllum spicatum*
hydrilla	*Hydrilla verticillata*
parrotfeather	*Myriophyllum aquaticum*
curlyleaf pondweed	*Potamogeton crispus*
sago pondweed	*Potamogeton pectinatus*
FREE-FLOATING WEEDS	
waterhyacinth	*Eichhornia crassipes*
waterlettuce	*Pistia stratiotes*

*Barnyardgrass and giant reed are not true aquatic weeds, but they pose serious problems for aquatic site managers.

SIDEBAR 6

Problems Caused by Aquatic Weeds

Aquatic weeds cause problems when they

- ☐ impede water flow—resulting in floods, water loss through seepage and evaporation—and damage canals
- ☐ clog pipes, culverts, and water intakes
- ☐ hinder navigation
- ☐ decrease production in fish hatcheries and rice fields
- ☐ interfere with aquatic recreation
- ☐ increase health hazards by providing shelter for disease-carrying mosquitoes and habitat for pests such as leeches
- ☐ provide escape cover for non-native fish species
- ☐ kill fish when decaying weeds reduce oxygen levels in the water or when overabundant submersed weeds consume excessive oxygen at night
- ☐ prevent the oxygenation of water bodies by covering the water's surface
- ☐ create pollution when decaying masses of weeds contaminate drinking water
- ☐ displace native plants, depriving native animals of their natural habitats and food supplies
- ☐ provide avenues for weed seed introduction into agricultural fields when emersed weeds along banks are left uncontrolled

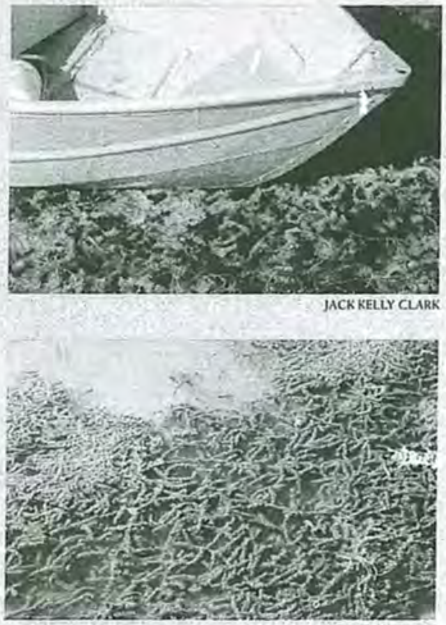

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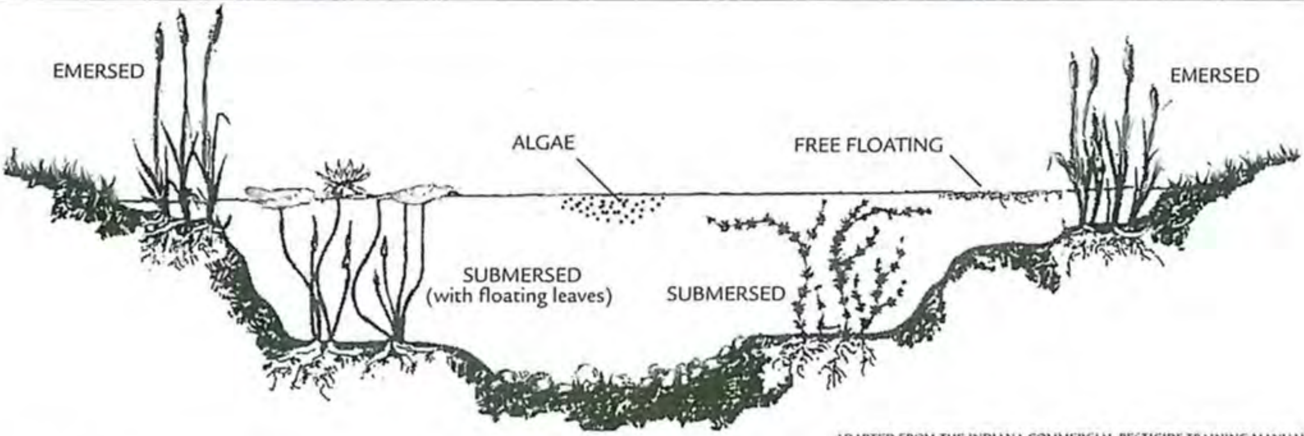
FIGURE 1-1.

Weed-clogged waterways make boat passage difficult (top). Excessive aquatic weed growth, like that of the egeria shown in the bottom photo, disrupts the predator/prey relationship among fish, because prey have more hiding places.



ADAPTED FROM THE INDIANA COMMERCIAL PESTICIDE TRAINING MANUAL

FIGURE 1-2.

The four groups of aquatic weeds include algae, emersed plants, submersed plants, and free-floating plants.

FIGURE 1-3.

Hundreds of species of algae grow in California's fresh waters.

CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE

tous, or branched (Charophytes). They grow best in well-lighted, shallow water that is rich in organic matter and nutrients. Hundreds of species of algae grow in California's fresh waters (Figure 1-3). Table 1-2 lists some of the most troublesome species.

Emersed Weeds

Emersed weeds are flowering aquatic plants with roots, stems, and leaves. Emersed weeds are rooted in the sediment, usually at water depths of less than 2 to 3 feet, while most of their stems, leaves, and flowers grow above the water's surface. Emersed leaves of individual species may differ from the plant's *submersed* leaves. Like all flowering plants, emersed weeds are seed-bearing, but most also reproduce by vegetative structures such as *rhizomes*, *tubers*, and *turions*. They produce rhizomes for overwintering. Turions (Figure 1-4) are modified *dormant* leaf buds.

CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE

FIGURE 1-4.

This hydrilla turion is a modified dormant leaf bud.

Examples of emersed weeds are cattail (Figure 1-5), alligatorweed, waterprimrose, bulrush, reed canarygrass, and arrowhead. In addition, giant reed and purple loosestrife (Figure 1-6) often grow in or near water. Although these are *terrestrial* (not aquatic) plants, they pose problems for aquatic site managers. Management methods for these plants are the same as or similar to those for emersed aquatic weeds.

Submersed Weeds

Almost all parts of submersed weeds remain beneath the water's surface, and most species root in the sediment. Stems of these weeds generally lack rigid, self-supporting cellular tissue and are thus supported by the water. Certain species of submersed weeds have leaves or flowers that float on the water's surface or rise slightly above it. The three types of submersed weeds are rooted, without floating leaves; rooted, with floating leaves; and without roots. Rooted, submersed weeds without floating leaves include egeria, common elodea, hydrilla (Figure 1-7), naiad, Eurasian watermilfoil, sago pondweed, and parrotfeather. Rooted, submersed weeds with floating leaves include American pondweed, American lotus, fragrant waterlily, and spatterdock. Coontail is the only submersed weed without roots.

Free-Floating Weeds

Weeds in this group float freely on the water's surface. Examples are

TABLE 1-2.

Troublesome Species of Algae.

PLANKTONIC	FILAMENTOUS	BRANCHED
Anabaena (blue-green)	*Cladophora* (cottony)	*Chara*
Chlorella (green)	*Hydrodictyon* (net-like)	*Nitella*
Microcystis (blue-green)	*Pithophora* (horsehair clump)	
Nostoc (blue-green)	*Spirogyra* (slimy)	

KATHY KEATLEY GARVEY

FIGURE 1-5.

Cattails are emersed aquatic weeds, rooted in shallow water.

duckweed, water ferns, waterlettuce, and waterhyacinth. Waterhyacinth (Figure 1-8) is considered one of the world's most troublesome aquatic weeds.

Table 1-3 lists examples of emersed, submersed, and free-floating aquatic weeds.

CHARACTERISTICS OF AQUATIC WEEDS

Prolific growth and reproduction characterize most aquatic weeds. Through competition they often displace nati\ or other more desirable plant species.

Reproduction

Reproduction is an important factor in determining whether an aquatic plant is a weed. Weeds must have the capacity to invade a habitat successfully, reinfest the area despite control efforts, and spread rapidly.

Sexual Reproduction. Sexual reproduction results in seed formation, which allows a weed species to survive during long periods of adverse conditions. Weeds that reproduce sexually generally bear their flowers above the water. Pollination usually occurs at the water's surface, although there are some species that are pollinated

MIKE PITCAIRN, CDFA

FIGURE 1-6.

Purple loosestrife often grows in or near water, causing problems for aquatic site managers.

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FIGURE 1-7

Hydrilla is an example of a rooted, submersed plant without floating leaves.

underwater. Aquatic weed seeds sometimes lie dormant in the bottom sediment for years until conditions favor germination. Prolific seed production, however, does not ensure survival of a weed species. Other factors, including availability of nutrients and light, are important for seedling establishment. Waterlilies are an example of a sexually reproducing aquatic weed.

TABLE 1-3.

Types of Aquatic Weeds.

EMERSED	SUBMERSED	FREE-FLOATING
alligatorweed *Alternanthera philoxeroides*	egeria *Egeria densa*	common duckweed *Lemna minor*
arrowhead *Sagittaria* spp.	common elodea *Elodea canadensis*	common watermeal *Wolffia columbiana*
bulrush *Scirpus* spp.	coontail *Ceratophyllum demersum*	giant duckweed *Spirodela polyrhiza*
cattail *Typha* spp.	hydrilla *Hydrilla verticillata*	mosquitofern *Azolla caroliniana*
common reed *Phragmites australis*	leafy bladderwort *Utricularia foliosa*	salvinia *Salvinia* spp.
giant reed *Arundo donax*	naiad *Najas* spp.	waterhyacinth *Eichhornia crassipes*
purple loosestrife *Lythrum salicaria*	parrotfeather *Myriophyllum aquaticum*	waterlettuce *Pistia stratiotes*
waterprimrose *Ludwigia* spp.	sago pondweed *Potamogeton pectinatus*	

Asexual Reproduction. Asexual reproduction occurs through new plants arising from vegetative structures such as stem fragments, stolons, rhizomes, root crowns, tubers, and turions. Many aquatic weeds reproduce in this manner. The ability of fragments and specialized vegetative structures to *overwinter* contributes greatly to the survival of asexually reproducing weed species. For example, tubers can remain dormant in the bottom sediment indefinitely during unfavorable conditions and begin growing when conditions turn favorable. Table 1-4 lists modes of asexual reproduction in some aquatic weeds.

Both Sexual and Asexual Reproduction. Some aquatic weeds, such as cattail (Figure 1-9) and sago pondweed, reproduce both sexually and asexually. Such plants have the best chance of survival, because compared to other aquatic plants, they are maximally adapted to withstand unfavorable growth conditions. For

TABLE 1-4.

Types of Asexual Reproduction among Common Aquatic Weeds.

MODE OF ASEXUAL REPRODUCTION	EXAMPLES OF AQUATIC WEEDS
fragments	egeria, hydrilla, waterhyacinth
green-root crowns	common elodea, hydrilla
rhizomes	arrowhead, egeria, cattail, hydrilla, pondweed, waterlily
spores	mosquitofern, salvinia
stolons	alligatorweed, arrowhead, egeria, Eurasian watermilfoil, hydrilla, waterhyacinth
tubers	hydrilla, sago pondweed
turions	hydrilla, curlyleaf pondweed
winter buds	American pondweed, variable pondweed

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FIGURE 1-8.

Waterhyacinth is considered one of the world's most troublesome aquatic weeds.

instance, habitat disruption that kills many aquatic plants may not eradicate these major weeds.

KATHY KEATLEY GARVEY

FIGURE 1-9.

Cattail reproduces both sexually and asexually.

Competitive Ability

An important distinguishing characteristic of aquatic weeds is their superior ability to compete for available nutrients and light and their propensity to crowd out other plants. They do this through early emergence and rapid growth, which allows them to dominate space and gain access to nutrients before other plants emerge. As an example, alligatorweed can quickly colonize an environment and, under optimal conditions, double its population within just a few days.

Many aquatic weeds compete by forming dense mats. Hydrilla, for instance, roots in the sediment, but 70 percent of its mass floats in the upper 1 to 2 feet of surface water. Its mats grow so thick that waterfowl can walk on them. These mats quickly become nuisances by clogging waterways, making the water inaccessible to boaters and swimmers.

Certain aquatic plants compete by producing chemicals that limit the growth of other plants. This process, known as *allelopathy*, gives the plant an advantage by reducing competition for essential nutrients, light, and water. One aquatic weed exhibiting allelopathy is a blue-green alga that produces a chemical poisonous to plants and other organisms, including fish, cattle, and people. Another weed growing in aquatic environments that exhibits allelopathy is saltcedar, a *riparian* tree that exudes high concentrations of salt from its leaves (Figure 1-10). Rainfall washes these salts off of the leaves, and the salts concentrate in the soil beneath the trees. The high salt content inhibits the growth of non-salt-tolerant plants.

Many aquatic weeds survive uniquely well under an array of adverse conditions. Persistent weeds such as hydrilla, common elodea, salvinia, and waterhyacinth are adapted to a wide range of habitat conditions. For example, hydrilla thrives equally well in low-nutrient (*oligotrophic*) or high-nutrient (*eutrophic*) water. It survives well in a wide pH range and can tolerate a fairly high degree of salinity.

JACK KELLY CLARK

FIGURE 1-10.

Saltcedar reduces competition from other plants by producing chemicals that inhibit their growth.


CDFA


CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE

FIGURE 1-11.

Alligatorweed (closeup at left) is a persistent broadleaf aquatic plant that also invades terrestrial areas. The photo at right shows a large stand of alligatorweed along a rural roadside.

Hydrilla can also tolerate water level fluctuations and endures strong water currents. Another persistent, broadly adapted species is alligatorweed (Figure 1-11), which grows prolifically in terrestrial and aquatic environments.

HOW AQUATIC WEEDS ARE INTRODUCED AND DISPERSED

Many aquatic weeds are exotic, meaning that they are not native to an area. Generally, their introduction is caused by human actions, either intentional or accidental. Once introduced, these exotics may spread by various means, including wind and water movement, animals, and people. They often have competitive advantages over native plants, because natural enemies that restrict their spread and proliferation in their native habitats are absent in their new locations.

People. Many people are attracted by the showy flowers of such weeds as purple loosestrife and waterhyacinth (Figure 1-12) and have unwittingly contributed to the spread of these weeds by collecting them from one area and planting and growing them in another. These human activities, as well as boating, shipping, and the importing of plants and fish, are the chief means by which aquatic weeds are introduced to an area (see Sidebar 7). During the last century aquarium plant dealers imported such weeds as salvinia, arrowhead, and waterhyacinth. Current laws make it illegal to import any weed on the Federal Noxious Weeds List.


JACK KELLY CLARK

FIGURE 1-12.

People attracted by the showy flowers of aquatic plants, such as this waterhyacinth, contribute to the spread of these weeds.

SIDEBAR 7

Unwanted Organisms Travel via Ship Ballast Water

Cargo ships carry water in large *ballast* tanks. The ballast water helps balance the vessels and keeps ships sitting lower in the water when they are not carrying cargo. When these ships unload ballast water at their destinations, they also discharge any hitchhiking organisms. Throughout the world, more than 3,000 species of aquatic animals and plants have been transported in ballast water. These unwanted organisms include alligatorweed, duckweed, purple loosestrife, zebra mussel, and the Chinese mitten crab.

The discharge of ballast water from foreign ships is blamed for at least 23 of the 212 exotic aquatic animal and plant species now found in the San Francisco Bay and Sacramento-San Joaquin Delta. In fact, a 1995 U.S. Fish and Wildlife Service report showed that the San Francisco Bay is the most invaded aquatic ecosystem in North America. One invader is the Chinese mitten crab, native to mainland China and coastal areas along the Yellow Sea. It was first detected in the San Francisco Bay in 1992. Juvenile crabs burrow into levees and banks, and although the burrows are no more than 12 inches deep, a large number of mitten crab burrows can weaken levees. The mitten crab is a nuisance to sport anglers, because adult crabs steal bait. It is also a nuisance in, and potentially may have an economic impact on, the crayfish and bay shrimp fisheries.

Chinese mitten crab.

GARY GOLDSMITH, FAIRFIELD DAILY REPUBLIC

The zebra mussel, native to the Caspian and Black Seas, entered the Great Lakes area via ballast water in 1986 and soon spread throughout the eastern United States. The U.S. Fish and Wildlife Service estimated the economic and environmental impact of the zebra mussel invasion in the 1990s to be $5 billion. This invasion led to a 1993 federal ban on discharge of ballast water into the Great Lakes.

The prolific zebra mussel now threatens the western United States, including California. State Department of Food and Agriculture officials first intercepted zebra mussels in California on a trailered boat at the Needles border inspection station in November 1993, a month after CDFA inspections began. CDFA experts now fear invasions of the San Francisco Bay and the Sacramento-San Joaquin Delta.


FIGURE 1-13. JACK KELLY CLARK

Wind and water hasten the spread of aquatic weeds like this mosquitofern.


FIGURE 1-14. JACK KELLY CLARK

Seeds can remain in the intestinal tract of some birds for a long time and can be transported many miles before being excreted and germinating.

Recreational and commercial activities also contribute to aquatic weed dispersal once these weeds have been introduced. For example, boat propellers may snag fragments of hydrilla and Eurasian watermilfoil in one location and transport them to new locations.

Wind and Water. Both wind and water hasten the spread of aquatic weeds. Wind disperses seeds and spores of some species, such as cattail, bulrush, giant reed, and mosquitofern (Figure 1-13). Water, often aided by wind, transports vegetative fragments, turions, seeds, and other parts of aquatic plants. Wind and water currents readily disperse whole floating plants, such as waterhyacinth. Many seeds or other reproductive plant parts float in a dormant state for days or months and then begin to develop when conditions become optimal.

Animals. Animals unknowingly disperse seeds and vegetative fragments. For instance, foxes may carry cattail seeds on their coats, and kingfishers diving for fish may transport duckweed from one site to another. Seeds can remain in the intestinal tracts of some birds long enough to be transported thousands of miles (Figure 1-14). The seeds of many species of plants can sprout even after passing consecutively through the digestive tracts of several animals.

CONDITIONS FOR AQUATIC WEED GROWTH

To manage aquatic weeds, it is crucial to understand the conditions that promote their growth. The important factors are light, water clarity, nutrients, temperature, and water chemistry. Also, a stable soil or *substrate* and the absence of grazers, diseases, competitive plants, and natural enemies are important requirements. In addition, the ability of certain aquatic weeds to tolerate herbicides provides some weeds with a competitive advantage in herbicide-treated areas.

Light

Submersed plants cannot grow in water that is so murky or muddy that light is completely blocked. That portion of water having enough light to support growth is called the *photic zone*. The bottom of the photic zone supports very few plants, since the light intensity there equals 1% of full sunlight. The photic zone may extend only a few inches below the surface in silty ponds or muddy marshes. However, in extremely clear lakes the photic zone may extend 35 feet or more below the surface. The photic zone of most California lakes ranges from 10 to 12 feet. In shallow water, the photic zone often extends to the sediment, where rooted plants take hold.

Water Clarity

Water color, algal growth (Figure 1-15), and the color and amount of suspended solids affect water clarity. In some bogs and marshes, decaying plant matter stains the water the color of strong tea. Suspended solids that affect water clarity include clay, silt, industrial wastes, and sewage.

Aquatic environment managers sometimes use a light meter or simple *Secchi disk* (Figure 1-16) to measure water clarity. A Secchi disk is a weighted 8-inch plastic disk with alternating white and black quadrants. The disk is lowered into the water on a calibrated line until it is no longer visible. By measuring this depth you can get a measure of the water clarity.

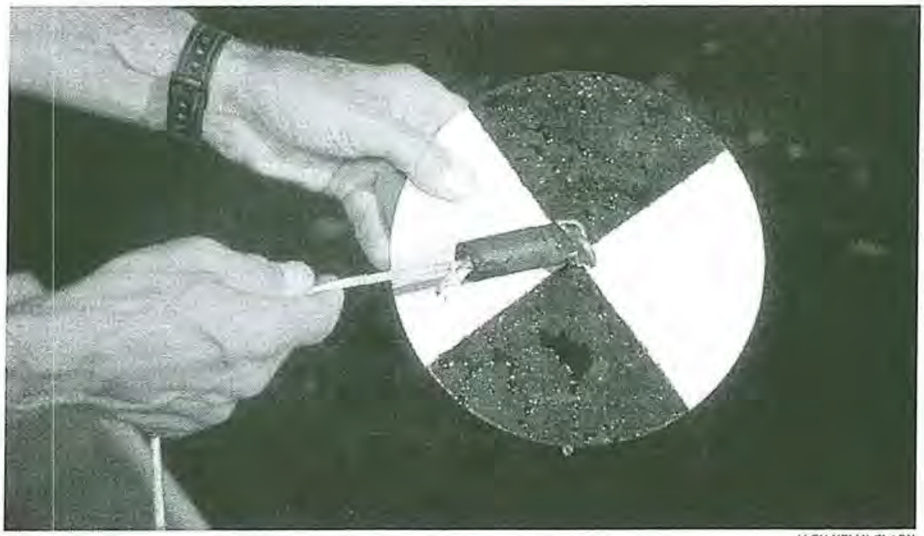
Nutrients

Nutrients that affect plant growth include nitrogen, phosphorous, iron, and potassium. Nutrient-rich waters usually foster and can support heavy

KATHY KEATLEY GARVEY

FIGURE 1-15

Algal buildup in a body of water affects water clarity.



JACK KELLY CLARK

FIGURE 1-16.

A Secchi disk is used to measure water clarity. It is attached to a calibrated line and lowered into the water until it is no longer visible. The depth to the point where the disk is no longer visible provides a measure of water clarity.

growths of algae and other aquatic weeds. Bodies of water that receive runoff from septic tanks, sewage treatment plants, storm drains, or fertilized lawns or fields have especially high concentrations of nutrients (Figure 1-17).

Temperature

Most aquatic weeds grow well in warm water, especially in the spring and early summer. They usually reach maximum size and density in mid to late summer. Water levels are generally lower in summer than in winter, and since shallow water warms faster, it typically provides plants with a longer growing season than deep water. Many submersed weeds do well at temperatures between 68° and 95°F, but some can survive in extremes, such as near 0° or as high as 104°F. Common elodea acclimates well to lower temperatures, while hydrilla thrives at much higher temperatures than most other submersed weeds.

Temperature is also important in determining the geographic distribution of aquatic weeds. Many parts of California have longer growing seasons and warmer water temperatures than the colder climates of the Sierra, the Pacific Northwest, and the North Central and New England states. Warmer temperatures in California's San Joaquin and Sacramento Valleys, the Imperial Valley, and the state's central and southern coastal areas allow a greater variety of aquatic weeds to become established and flourish. Cooler mountain temperatures and freezing winter weather generally prevent some introduced aquatic weeds from surviving long enough to become established and begin reproducing. However, a few underwater plants living in deep water (even under ice) can survive extreme winter temperatures.

FIGURE 1-17.

Runoff of nutrients from surrounding fertilized plants can create a nutrient-rich pond such as the one pictured here.

KATHY KEATLEY GARVEY

Water Chemistry

All natural waters contain dissolved salts and minerals, and in their various concentrations these can affect plant growth. Also, the hardness, softness, and pH of water have an effect on plant growth. Hard water has higher calcium and magnesium concentrations and tends to foster more weed growth than soft water. Soft water is often stained with organic substances that block light penetration.

Stable Substrate

Unstable sand, heavy currents, and high water flow are unfavorable to the growth of many aquatic weeds such as bulrush and cattail. Rooted, floating weeds such as waterlily (Figure 1-18), watershield, and American pondweed grow better in shallow aquatic environments with gradually sloping sides than in deep environments with steep sides.

FIGURE 1-18. KATHY KEATLEY GARVEY

Rooted, floating aquatic weeds, such as this fragrant waterlily, thrive in shallow-water areas.

Absence of Grazers, Diseases, Competitive Plants, and Natural Enemies

Under the right conditions, exotic species are able to invade and rapidly colonize aquatic environments.

Whereas an aquatic plant may not be a noxious weed in its native habitat because grazers (Figure 1-19), diseases, competitive plants, and natural enemies keep it in check, once outside the native habitat and away from these organisms, some aquatic plants become aggressive weeds.

Tolerance to Herbicides

Systemic aquatic herbicides kill roots, but most do not kill tubers, rhizomes, or seeds—all reproductive structures. Aquatic weeds that have these reproductive structures have a competitive advantage in treated areas over plants that do not have these structures. For example, rhizomes of cattail or bulrush often extend several feet from the parent plant. After the herbicide dissipates, the plant simply regrows from these rhizomes.

FIGURE 1-19. VALERIE VAN WAY

Grazers can contribute to aquatic weed management. Here cows are feeding on waterhyacinth.

REVIEW QUESTIONS

(answers on page 145)

1. Which of the following is *not* a characteristic of noxious aquatic weeds?

☐ a. They grow rapidly
☐ b. They displace native vegetation
☐ c. They interfere with uses of the body of water
☐ d. They reproduce only by asexual means

2. Which is *not* one of the four main categories of aquatic weeds?

☐ a. Submersed
☐ b. Emersed
☐ c. Free-floating

3. An example of an emersed weed is:

☐ a. Waterlily
☐ b. Cattail
☐ c. Egeria
☐ d. Hydrilla

4. An example of a submersed weed is:

☐ a. Alligatorweed
☐ b. Waterprimrose
☐ c. Sago pondweed
☐ d. Arrowhead

5. An example of a free-floating weed is:

☐ a. Common duckweed
☐ b. Waterprimrose
☐ c. Arrowhead
☐ d. Waterlily

6. Which is considered the world's most troublesome aquatic weed?

☐ a. Cattail
☐ b. Waterhyacinth
☐ c. Hydrilla
☐ d. Egeria

7. When massive quantities of decomposing aquatic weeds deplete oxygen levels, this can result in:

☐ a. Prolific seed production
☐ b. Fish kills
☐ c. Asexual reproduction
☐ d. Sexual reproduction

8. Which is *not* characteristic of asexual reproduction?

☐ a. Production of tubers
☐ b. Production of rhizomes
☐ c. Production of seeds
☐ d. Production of stolons

9. Aquatic weeds that reproduce both sexually and asexually:

☐ a. Do not exist
☐ b. Exist only in the warmer climates
☐ c. Cannot survive
☐ d. Have the best chance of survival

10. Aquatic weeds that compete for available nutrients and light tend to crowd out other plants through:

☐ a. Formation of tubers and turions
☐ b. Delayed emergence
☐ c. Early emergence and rapid growth
☐ d. Formation of rhizomes, tubers, or turions

11. Certain aquatic weeds produce chemicals that inhibit the growth of other plants. This process is called:

☐ a. Riparian
☐ b. Eutrophic
☐ c. Oligotrophic

12. An *exotic* aquatic weed is:

☐ a. One with showy flowers
☐ b. Different from other plants in the area
☐ c. Not native to the specific area
☐ d. One that only blooms at night

13. Aquatic weeds are introduced to an area through:

☐ a. Oligotrophic and eutrophic means
☐ b. Allelopathy
☐ c. Short-term temperature fluctuations
☐ d. Wind and water movement, animals, and people

14. That portion of water having enough light penetrating it to support growth is called the:

☐ a. Secchi zone
☐ b. pH zone
☐ c. Photic zone
☐ d. Salinity zone

15. Aquatic environment managers sometimes use a black-and-white disk to measure water clarity. This is known as a:

☐ a. Ballast
☐ b. Secchi disk
☐ c. Eutrophic disk
☐ d. Oligotrophic disk

16. Hard water is higher in:

☐ a. Phosphorous and magnesium
☐ b. Sodium and magnesium
☐ c. Calcium and potassium
☐ d. Magnesium and iron

2 Identifying Aquatic Weeds


JACK KELLY CLARK

Before you begin any type of aquatic weed control, you must first identify the pest plants.

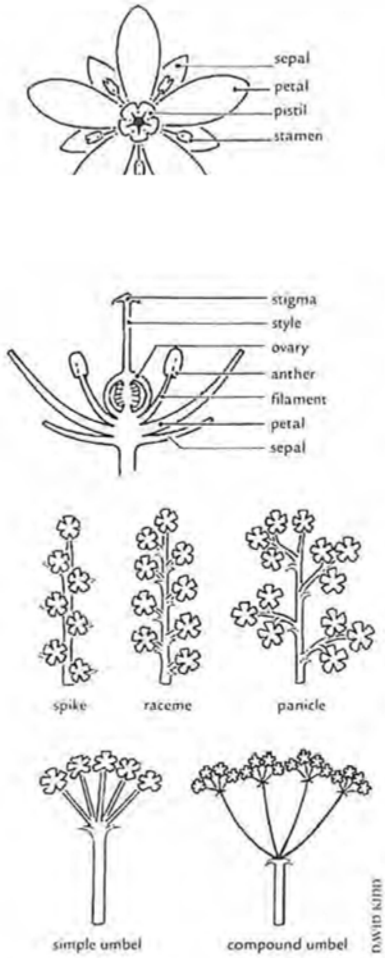


FIGURE 2-1.

Sometimes weeds can be identified by their unique flower structures and arrangements.

YOU MUST IDENTIFY AQUATIC weeds before you begin any type of

similarities and differences among stems, leaves, and flowers (Figure 2-1). Leaf arrangement is also a good identifying characteristic, and so are fruits, seeds, and special rooting structures (Figure 2-2).

A simple way to identify aquatic weeds is to compare specimens you collect in the field with photographs and drawings like the ones included in this chapter. If you are unable to identify specimens using these sources, use identification keys or send weeds to an expert for identification. Advisors at University of California Cooperative Extension offices, located in most counties throughout the state, can assist in identifying aquatic weed specimens. You can also mail samples to the Plant Pest Diagnostics Center at the California Department of Food and Agriculture. (See Sidebar 8 for information on how to prepare samples for mailing.)

A standardized international classification system using scientific names

similarities and relationships. For example, hydrilla is in the *genus Hydrilla*, and it has been given the specific epithet *verticillata* to distinguish it from all other plants in this genus. Its species name, *Hydrilla verticillata,* consists of both the genus name and its specific epithet. It is very useful to know scientific names when you are trying to locate information about aquatic weeds. A good way to determine scientific names is by using a weed identification manual that has a cross-reference to common names.

Identifying a flowering plant begins with deciding which of two major groups it belongs to, *dicotyledons* (dicots) or *monocotyledons* (monocots). Dicots, also known as broadleaves, include the following aquatic plants: waterlily, waterprimrose, Eurasian watermilfoil (Figure 2-3), parrotfeather, and alligatorweed. Monocots are usually narrow-leaved plants such as

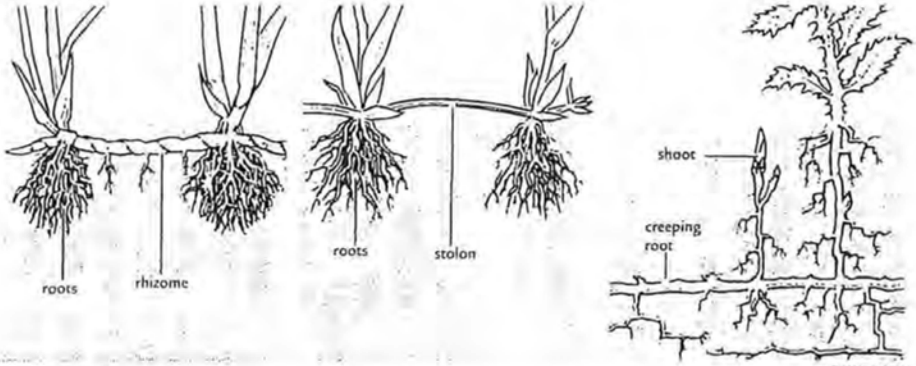


FIGURE 2-2.

Special rooting structures are useful in identifying aquatic weeds.

SIDEBAR 8

Sampling and Sending Aquatic Weeds for Identification

SAMPLING

- ☐ Choose several plants that represent the species.
- ☐ Include stems, leaves, flowers (if present), and roots.
- ☐ Dig up rooted weeds to prevent damage to roots.
- ☐ Rinse plants lightly after digging to remove excess soil.

PREPARATION

- ☐ Keep plants in an ice chest while you are in the field. If they cannot be shipped immediately, store them in a refrigerator.
- ☐ Dry off the plants and put them in plastic bags or press them between sheets of absorbent paper and encase in heavy cardboard for protection.

LABELING

Attach a label to the outside of each sample. Include the following information on labels:

- ☐ Location where samples were taken, including name of lake or river, if appropriate, and nearby crossroads.
- ☐ Description of specific characteristics of the site where the plants were growing.
- ☐ Whether plants are annuals or perennials.
- ☐ Your name, address, and telephone number.
- ☐ Date samples were taken.
- ☐ Any other information that would help in the identification of the plants.

SHIPPING

- ☐ Contact the person or laboratory who will receive samples to determine the best method of shipping and to inform them that samples will be arriving.
- ☐ Pack samples in a sturdy, well-insulated container to prevent crushing or heat damage.
- ☐ Mark package clearly and request shipper to keep it in a cool location.
- ☐ Ship packages early in the week so they will arrive before a weekend.

grasses, sedges, and *rushes.* Aquatic monocots include cattail, horned pondweed, and widgeongrass. Some monocot aquatic weeds, however, resemble broadleaf species. These include common elodea, arrowhead, pondweed, common duckweed, and waterhyacinth.

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FIGURE 2-3.

Eurasian watermilfoil is an example of a dicot.

Using Growth Habits and Life Cycle for Identification

Sometimes knowing a plant's growth habits and life cycle can help you identify it. Plants have *annual, biennial,* or *perennial* life cycles. Annuals live 1 year or less. They sprout from seeds, mature, and produce seeds for the next generation during this period. Biennials usually live for two growing seasons. They sprout and undergo vegetative growth during the first season, then flower, produce seeds, and die the following season. Perennial plants live 3 or more years; some species live indefinitely. Many perennials lose their leaves or die back entirely during the winter (herbaceous perennials), but regrow each spring from roots or underground storage organs such as tubers, *bulbs,* or rhizomes. For many perennials, these storage organs also provide the chief means of dispersal.

Barnyardgrass, ducksalad, and naiad are examples of annuals, but most aquatic weeds are perennials. Some of the world's most troublesome aquatic weeds include the perennials waterhyacinth, hydrilla, Eurasian watermilfoil, and purple loosestrife.

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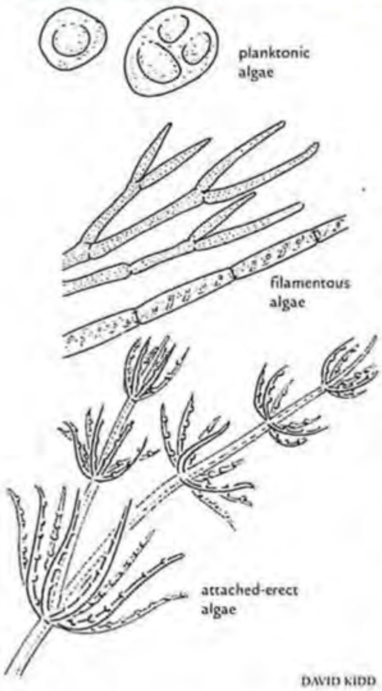

DAVID KIDD

FIGURE 2-4.

Algae, such as that shown in this pond (top), are single-celled or multicelled plants that contain chlorophyll but lack conducting tissues and true roots, leaves, or flowers. The drawing illustrates the three types of algae: planktonic, filamentous, and attached-erect (or branched).

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FIGURE 2-5.

Cladophora *is a filamentous alga that looks cottony.*

ALGAE

Algae can be divided into three general categories, based on their size and shape (Figure 2-4). These categories are planktonic, filamentous, and branched.

Planktonic Algae

Planktonic algae are single-celled plants or small colonies of cells that attach to each other and float freely in or on the surface of water. Most planktonic algae are beneficial, because they convert nutrients into food for fish and other organisms, forming the base of the food chain. They also provide shelter and habitat for fish, waterfowl, and other wildlife. And, like all plants, they produce oxygen through photosynthesis.

However, excessive growth of planktonic algae can be harmful to other aquatic organisms and can make water unsuitable for other uses. Planktonic algae colors water green, bluish-green, yellowish-green, red, or brown in an overgrowth called *bloom*. Excessive bloom, especially common in nutrient-rich or fertilized water, can

- deplete oxygen levels and produce fish kills
- sicken or kill livestock and wildlife that happen to drink the water
- cause allergic reactions in some people
- emit a sewage-like odor as algae die and decompose

Blue-green algae are the most common nuisance planktonic algae and include the genera *Microcystis* and *Nostoc*, which produce toxins harmful to livestock and other organisms. *Chlorella* is a common green planktonic alga that can be a nuisance. Under favorable conditions it grows very rapidly, completing its reproductive cycle in less than 24 hours.

Habitat: lakes, ponds, canals, and ditches, especially those that are nutrient rich.

Filamentous Algae

Filamentous algae are multicelled plants whose cells are attached end-to-end, forming long threads or *filaments*. When large numbers of filaments become intertwined they create mats on the bottom or surface of bodies of water. The texture of filamentous algae can be slimy (*Spirogyra*), cottony (*Cladophora*, Figure 2-5), net-like (*Hydrodictyon*), or resembling horsehair (*Pithophora*). Some filamentous algae attach to docks, seawalls, boats, walls of concrete-lined canals, and similar surfaces. Other problems caused by filamentous algae include

- blocked sunlight to plants below
- oxygen depletion, leading to fish kills
- offensive odors as plants die and decompose

Habitat: Lakes, ponds, and canals, especially those that are nutrient rich.

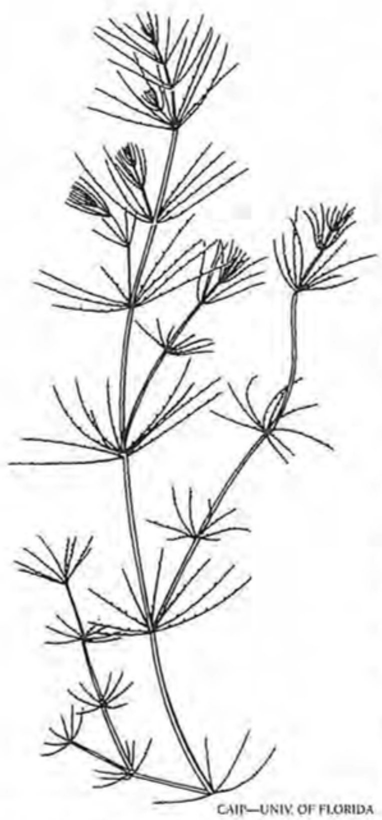

FIGURE 2-6.

Chara *spp. feel gritty and emit a musky odor.*

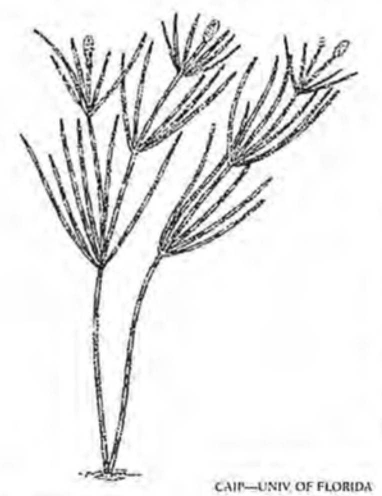

FIGURE 2-7.

Nitella *spp. feel smooth and lack a strong odor.*

Branched Algae

Branched algae, also known as attached-erect algae or Charophytes, resemble *vascular* plants, though like all algae they have no true roots, leaves, or flowers. They are submersed, multicelled, branching plants with holdfast structures that anchor them to the sediment. While Charophytes provide valuable habitat for fish, they can become troublesome, especially when they grow to the surface.

The two most troublesome Charophytes in aquatic environments are the genera *Chara* and *Nitella*. *Chara* spp. (Figure 2-6) have a gritty texture because of calcium carbonate deposits on their surfaces, and they emit a musky odor. *Chara* spp. often cause problems in highly alkaline ponds, preferring pH 8 or higher. *Chara* spp. are usually gray-green, but they may become brown or chalk-colored as they accumulate calcium carbonate. Once established, these plants are difficult to control. The other troublesome Charophytes, the *Nitella* spp. (Figure 2-7), can be distinguished from species of *Chara* by their lack of a strong odor and their smooth texture. In addition, they are more delicate and a darker green. **Habitat**: Ponds, lakes, rivers, and ditches.

EMERSED AQUATIC WEEDS

Emersed aquatic weeds are rooted in the sediment, extend above the water's surface, and have self-supporting plant structures. Emersed aquatic weeds include a large number of monocots, such as cattail, bulrush, and reed canarygrass. Broadleaf plants, such as purple loosestrife and waterprimrose, are also emersed aquatic weeds. Most of the emersed aquatic weeds that are described below are commonly found in California.

Alligatorweed (*Alternanthera philoxeroides*, Amaranth family). **Life cycle**: Perennial. **Habitat**: Shallow water, ditches, ponds, or very wet soil. It can also grow on dry land.

FIGURE 2-8.

Alligatorweed.

Alligatorweed (Figure 2-8) grows in large mats composed of interwoven, prostrate, hollow stems that root at the nodes. The weed also has erect stems that are usually 6 to 23 inches tall. Lance-shaped, green, waxy leaves grow opposite on the stem, and flowers are produced in a rounded, compact spike on a short stem. The white flower sepals are papery to the touch at maturity. The plant reproduces vegetatively from axillary buds and is capable of crowding out most competing species.

Arrowhead (*Sagittaria* spp., Waterplantain family, Figure 2-9). **Life cycle**: Annual and perennial. **Habitat**: Shallow edges of ponds, lakes, and streams, and in swamps, marshes, ditches, and rice fields.

The mature leaves of this weed are arrowhead shaped with widely spreading, pointed lobes on either side of erect, spongy leaf stems that clasp at the base of the plant. Some species have ribbon- or tonguelike submersed

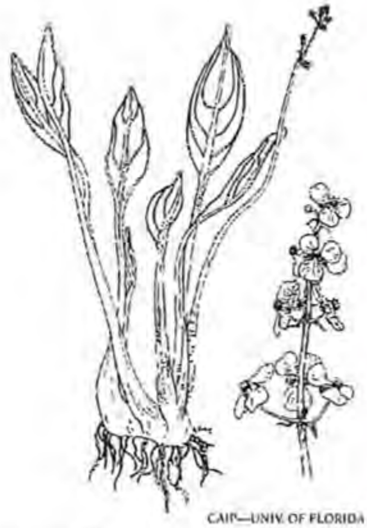
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FIGURE 2-9.

Arrowhead.


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FIGURE 2-10.

Bearded sprangletop.


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FIGURE 2-11.

Brazilian peppertree.

leaves. Arrowhead flowers are tiny, white, and extend up to 1 foot above the leaves. The one-seeded fruit are characteristically winged or beaked. The plant overwinters by means of tubers and reproduces by seed and stolons.

Barnyardgrass (*Echinochloa crus-galli*, Grass family). **Life cycle:** Annual. **Habitat:** Waste places, often wet sites, rice fields; also in lawns and hayfields and along roadsides.

Barnyardgrass is quite variable in appearance and occurs in a wide range of irrigated crops, including rice. Its flowering head does not droop, may be tinged purple, has bristles of varying lengths, and grows to 10 inches in length. The California system of water-seeding rice was established principally as a means to control barnyardgrass, and continuous flooding still provides good control. *E. colona*, *E. crus-pavonis*, and *E. oryzoides* are other related weed species commonly found in rice in California.

Bearded sprangletop (*Leptochloa fascicularis*, Grass family). **Life cycle:** Annual. **Habitat:** Irrigation and drainage canals, rice fields, marshes, and wetlands.

Bearded sprangletop (Figure 2-10) is a grass that grows in large clumps up to 4 feet tall. Young flower heads are dark green and become lighter as they mature, turning straw-colored after shedding seeds. Flower heads are branched, with each branch having several flower spikelets. Individual flower spikelets contain 7 to 11 flowers, and each flower has an *awn*.

Brazilian peppertree (*Schinus terebinthifolius*, Sumac or Cashew family). **Life cycle:** Perennial. **Habitat:** Prefers warm-climate creeks, washes, and canyons and is both aquatic and terrestrial.

Brazilian peppertree (Figure 2-11) is an aggressive shrub or small tree whose leaves have 3 to 13 pinnately arranged leaflets that are each about 1 to 2 inches long. The leaf midrib is reddish and often has wings. The leaves smell strongly of turpentine if crushed. Brazilian peppertree has very small white flowers and produces abundant fruit that are glossy and green when immature and bright red when they ripen. Reproduction is by seed, which are dispersed by gravity, water, and by birds that eat the fruit. The tree forms a very thick canopy that shades out most

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FIGURE 2-12.
Bulrush.

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FIGURE 2-13.
Burhead.

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FIGURE 2-14.
Cattail.

natural vegetation. It is an important wildland problem and is not always associated with aquatic areas.

Bulrush (*Scirpus* spp., Sedge family). **Life cycle:** Annual or perennial. **Habitat:** Marshes, lakes, ponds, stream banks, and other wet places.

Bulrushes (Figure 2-12) of various species are characterized by tall triangular or round-shaped stems that may be leafy or may have no leaves at all. These stems are technically called *culms*. Brownish flowers are borne in clusters at the ends of the stems. River bulrush (*S. fluviatilis*), a perennial sedge, has three to five leaves just below the flower cluster and extensive rhizomes that produce tubers from which the plant reproduces vegetatively.

Burhead (*Echinodorus berteroi*, Waterplantain family). **Life cycle:** Perennial. **Habitat:** Shallow, flooded areas, including irrigation and drainage canals and rice fields.

Burhead (Figure 2-13) has elliptical leaves and is sometimes confused with waterplantain (*Alisma* spp.). Burhead leaves are more crinkly than waterplantain leaves, and the leaf bottoms are more heart shaped. Burhead flowers grow in *whorls* and have three widely spaced white petals. The plant reproduces primarily from seed.

Cattail (*Typha* spp., Cattail family). **Life cycle:** Perennial. **Habitat:** Marshes, swamps, irrigation and drainage ditches, rice fields, and shallow waters up to 4 feet deep.

Cattail (Figure 2-14) has a cylindrical flower spike that can be more than 1 foot long and that is densely packed with tiny flowers. The mature flower spike is brown and about 1 inch in diameter. The upper portion of the spike is male, or *staminate*, and the lower portion is female, or *pistillate*. When it is time for seed to disperse, the spike comes apart and appears puffy and white. Flower spikes are borne at the end of stout, jointless stems that can reach 10 feet in height. Cattail leaves are long, narrow, and flat, and there are usually eight or more leaves per plant. Reproduction is by rhizomes and seed. This plant is sometimes confused with hardstem bulrush.

Common reed (*Phragmites australis*, Grass family). **Life cycle:** Perennial. **Habitat:** Swamps, marshes, and along lake shores, pond margins, and canals, especially in areas with slow currents and muddy bottoms. Also grows in river flood plains.

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FIGURE 2-15.

Common reed.

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FIGURE 2-16.

Dallisgrass.

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FIGURE 2-17.

Ducksalad.

This California native is less of a problem than the giant reed (see below). Common reed (Figure 2-15) has tall, erect stems that grow 6 to 15 feet high. Leaves are straplike, 1 inch or more wide, and up to 2 feet long. The loose flower heads are yellow to purple, 4 to 12 inches long, and consist of many 3- to 7-flowered spikelets. At maturity the flower heads have a silky appearance because of the fine hairs surrounding each flower. Common reed reproduces chiefly by rhizomes, since the seed seem unable to germinate underwater.

Dallisgrass (*Paspalum dilatatum*, Grass family). **Life cycle:** Perennial. **Habitat:** Marshes, canals, ditches, and other moist places.

Dallisgrass (Figure 2-16) has smooth stems that reach from 1 to 5½ feet in height. The inflorescences have three to five branches, or *racemes*, that are 1½ to 6 inches long and from which arise silky-haired spikelets borne in pairs on one side of the raceme. Each spikelet contains one seed, and a small brownish-black *ergot* often hangs from each seed. Dallisgrass leaves are flat, slightly hairy, and 4 to 12 inches long. Reproduction is by seed and rootstocks.

Ducksalad (*Heteranthera limosa*, Pickerelweed family). **Life cycle:** Annual. **Habitat:** Ponds, lakes, saturated soils, and rice fields. Found primarily in the Sacramento Valley.

Ducksalad seed germinate only under water or in saturated soil. The leaves are oval and waxy green and may be submersed, floating, or held above the water's surface. The plant's showy white flowers, borne singly on the flower stalk, have six narrow petals arranged in a star shape (Figure 2-17).

Giant reed (*Arundo donax*, Grass family). **Life cycle:** Perennial. **Habitat:** Streams, ditches, levee banks, and other moist places. Flourishes in all types of soils, including salty soils.

Giant reed (Figure 2-18) grows in clumps and is one of the tallest herbaceous perennial grasses, ranging between 12 and 25 feet in height. It has

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FIGURE 2-18.

Giant reed.

bamboolike hollow stems that are ¼ to 2 inches in diameter. A single clump of giant reed typically has hundreds of stems growing very close together. In spring and summer stems can grow as much as several inches per day. The blue-green leaves are 1 to 2½ inches wide and 12 inches long, and the plumelike inflorescence is 12 to 24 inches long. Giant reed forms very large, densely matted, fibrous underground root masses to support its tall stems and can form dense floating mats in streams and rivers. It reproduces by stem fragments and rhizomes.

Hoary cress (*Cardaria draba*, Mustard family). **Life cycle:** Perennial. **Habitat:** Edges of lakes, ponds, marshes and streams.

Hoary cress is a highly competitive, deeply rooted perennial that reproduces by seed and rootstocks. The creeping, extensive root system spreads both horizontally and vertically. Shoots arising from the rootstock grow to 2 feet high and are topped with compact, flat-topped clusters of small, white, 4-petaled flowers. The leaves are blue-green and lance-shaped. The lower leaves have leaf stems, while the upper leaves have two lobes that clasp the main stem. The leaves are often covered with fine white hairs, and each leaf is ½ to 2 inches long. The weed has heart-shaped seed pods.

Smartweed (*Polygonum* spp., Buckwheat family). **Life cycle:** Perennial. **Habitat:** Wet banks of ponds, lakes, streams, marshes, swamps, and ditches.

Smartweed (Figure 2-19) has upright stems that grow to 3 feet tall and form dense stands. The lower part of the stems root at the nodes. The leaves are narrow and lance shaped with smooth margins, and the flowers range from white to pink and grow in slender racemes. *P. hydropiperoides* is a native to California and is not a major problem. The non-native *P. pensylvanicum* and *P. persicaria* are more troublesome in aquatic areas of the state.

Nutsedge (*Cyperus* spp., Sedge family). **Life cycle:** Perennial. **Habitat:** Waterlogged soils, along canal and stream banks. Once established, however, it tolerates both normal irrigation conditions and drought. Yellow nutsedge grows throughout California, while purple nutsedge grows mainly in the southern portions of the state.

Nutsedges can be mistaken for grasses, but they are true sedges. Their leaves are thicker and stiffer than most grasses and are arranged in sets of three at the base, whereas grass leaves are arranged oppositely in sets of two. Also, nutsedge stems are triangular in cross section and solid, while grass stems are oval or almost flat in cross-section and are hollow. Nutsedge leaves are V-shaped in cross-section. Reproduction is mainly from rhizomes or tubers. The two most common species of nutsedge in California, yellow nutsedge (*C. esculentus*) and purple nutsedge (*C. rotundus*), reproduce from tubers formed on the rhizomes. However, these two species are not major aquatic pests.

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FIGURE 2-19.

Smartweed.

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FIGURE 2-20.

Purple ammannia. Photo at right shows the flowers and square stem.

Perennial pepperweed (*Lepidium latifolium*, Mustard family). **Life cycle:** Perennial. **Habitat:** Ditches, roadsides, waste places, and other wet areas.

Perennial pepperweed has a deep and extensive creeping root system. The plant grows up to 6 feet tall and has white flowers that are borne in dense, rounded clusters at the branch tips. The lower leaves are 12 inches long and are lance shaped, have long *petioles*, and are covered with a waxy layer. The upper leaves are smaller and have shorter petioles.

Purple ammannia (*Ammannia coccinea*, Loosestrife family). **Life cycle:** Annual. **Habitat:** Rice fields, lake and creek banks, drying ponds, and other wet areas.

Purple ammannia (Figure 2-20) has stems that branch extensively, and its narrow, pointed leaves clasp the stem in opposite pairs. Its flowers and fruit are bright rose-red. The flowers have four petals and grow in groups of three or four at the base of the leaves. The stems and leaves turn bright red as the plant matures. Mature plants range from 5 to 30 inches tall and reproduce by seed.

Purple loosestrife (*Lythrum salicaria*, Loosestrife family). **Life cycle:** Perennial. **Habitat:** Marshes, ponds, bogs, ditches, wetlands, stream banks, and saturated soils, including moist meadows and pastures.

Purple loosestrife (Figure 2-21) is characterized by showy spikes of magenta flowers that can be up to 2 feet long. Flowers have five petals and form dense clusters on the spike. The unserrated, lance-shaped leaves grow

FIGURE 2-21.
Purple loosestrife.

oppositely or in whorls of three. The plant is usually under 4 feet tall, but in nutrient-rich conditions it can reach 10 feet tall. It is difficult to eradicate an established stand of purple loosestrife. A single adult plant produces over 2 million seed annually, and the weed is also able to resprout from its extensive underground root network and from broken stems that fall onto the ground or into the water.

Reed canarygrass (*Phalaris arundinacea*, Grass family). **Life cycle:** Perennial. **Habitat:** Stream banks, woodlands, shores, and meadows.

This is a leafy perennial grass that reaches heights from 2 to 6 feet. It spreads by creeping rhizomes, creating a dense sod. It produces cream- to reddish-colored flowers in spikes, and the narrow leaves are blue-green with pointed tips. This weed can form dense stands along the margins of rivers and lakes. It is also cultivated by farmers for pasture and for hay or silage.

Saltcedar or tamarisk (*Tamarix* spp., Tamarisk family). **Life cycle:** Perennial. **Habitat:** Shores, riverbanks, washes, ditches, and flats, often in saline habitats. Grows in wetlands as well as arid habitats.

Saltcedar or tamarisk (Figure 2-22) is an invasive shrub or small tree that grows to 12 to 15 feet in height and forms dense thickets. It has a very deep taproot that can intercept and deplete water tables, disrupting natural aquatic systems. Saltcedar is fire-adapted, and the plant secretes salt from its leaves, which then washes off and can make the soil uninhabitable for native plants that are less salt-tolerant. In addition, its roots and stems can trap sediment, causing changes in river flow patterns.

Saltcedars have slender branches with gray-green, 1/16-inch-long leaves. Bark on young branches is reddish-brown, and on older branches bark becomes brownish-purple, ridged, and furrowed. The densely packed spikes of pink to white flowers form at the ends of branches and are about 2 inches long.

Scouringrush (*Equisetum hyemale*, Horsetail/Scouringrush family). **Life cycle:** Perennial. **Habitat:** Riverbanks, lakeshores, marshes, irrigation and drainage canals, rice fields, and wetlands.

Scouringrush (Figure 2-23) is an ancient plant that functions like a fern, though it does not look like a fern. The plant is characterized by dark green, slender, jointed stems that reach 2 to 5 feet in height. Stems are hollow between the black-ringed nodes, and leaves are reduced to small node-scales.

FIGURE 2-22.
Saltcedar growing along a stream bank (left) and closeup (right).

FIGURE 2-23.

Scouringrush.

The tip of each stem bears a brown conelike structure that contains reproductive spores. Scouringrush is a native plant in California and is mainly a problem in irrigation canals and ditches.

Smallflower umbrella sedge (*Cyperus difformis*, Sedge family). **Life cycle:** Annual. **Habitat:** Wet or moist areas, including flooded rice fields.

Smallflower umbrella sedge (Figure 2-24) reaches 12 to 16 inches in height at maturity. Each plant has several triangular stems that grow from the base of the plant. Each stem has leaves of differing lengths that arise just beneath globular flower heads. Individual flowers are green with brown markings and are arranged in spikelets. The flowers turn brown as they mature into fruiting heads. This plant produces thousands of seed and multiple generations per season.

Smooth cordgrass (*Spartina alterniflora*, Grass family). **Life cycle:** Perennial. **Habitat:** California coastline, estuaries, salt marshes, natural marshes, and mudflats.

Smooth cordgrass (Figure 2-25) is a tall, wide-leaved perennial grass that is native to the East Coast but outcompetes and hybridizes with California cordgrass (*S. foliosa*). Smooth cordgrass is a salt-tolerant plant that has tough, deep-seated rhizomes and can survive in many environments. It has ridged stems, and its inflorescences have loosely overlapping spikes.

Spikerush (*Eleocharis* spp., Sedge family). **Life cycle:** Annual or perennial. **Habitat:** These native plants occupy levees, shallow ditches, poorly drained soils, and flooded fields, including rice fields.

Spikerush (Figure 2-26) generally has green, round stems that are without

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FIGURE 2-24.

Smallflower umbrella sedge.

FIGURE 2-25.

Smooth cordgrass.

leaves. Stem lengths can be anywhere from 5 inches to 4 feet. At maturity each stem terminates in a single brown to black flowering head. Reproduction is from rootstocks and seed.

FIGURE 2-26.
Spikerush.

Swamp morningglory (*Ipomoea aquatica*, Morningglory family, Figure 2-27). **Life cycle:** Perennial. **Habitat:** Lakes and marshes, although it has not been discovered in California.

This semiaquatic native of India is on the Federal Noxious Weeds List. It produces viney stems that can reach 9 feet long and that root at the nodes. The flowers are white, pink, or pale lilac, and the leaves are arrow shaped.

Water smartweed (*Polygonum amphibium*, Buckwheat family). **Life cycle:** Perennial. **Habitat:** Edges of ponds, lakes, streams, marshes, swamps, and in ditches.

A native to California, water smartweed (Figure 2-28) has stems that trail through the water or mud and become erect at the tips, emerging out of the water. The plant freely produces roots and shoots at nodes that are lying in water. Leaves float and are smooth, leathery, and oval to widely lance

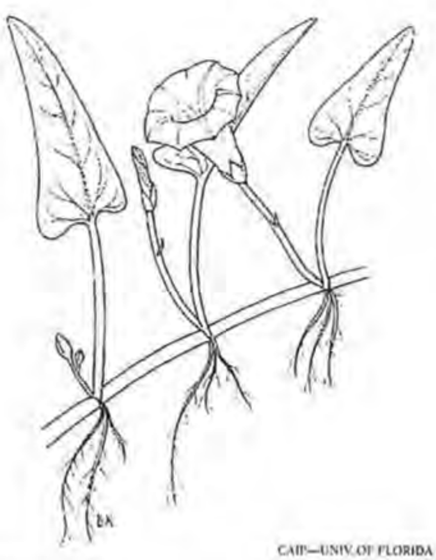

FIGURE 2-27.
Swamp morningglory.

FIGURE 2-28.
Water smartweed.

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FIGURE 2-29.
Watergrass.

shaped. Flowers are rose-pink in color and are held erect above the water.

Watergrass (*Echinochloa* spp., Grass family, Figure 2-29). **Life cycle:** Annual, sometimes perennial. **Habitat:** Wet places, including rice fields, mud flats, and along stream banks.

Early watergrass (*E. oryzoides*) and late watergrass (*E. phyllopogon*), along with barnyardgrass (see above), are the most serious weeds of rice in California. The early and late reference is in relation to their flowering times, not their germination times. Early watergrass has drooping flower heads and long awns. Late watergrass has erect to slightly drooping flower heads, and if it has awns, they are short. Watergrass grows upright, reaching from 6 inches to 6 feet in height. It may root at the lower nodes, forming large clumps. Junglerice (*E. colona*) is another watergrass that is common in California.

Waterhyssop (*Bacopa* spp., Figwort family). **Life cycle:** Annual, sometimes perennial. **Habitat:** Shallow water or wet soil, rice fields, and muddy places

Waterhyssop (Figure 2-30) forms floating masses of leaves and flowers on the water's surface. It has many branched and submersed stems that may develop roots at the nodes. Leaves occur in pairs and are almost round or slightly wedge shaped. They are arranged oppositely on the stems, are not stalked, and are about ½ to 1 inch long. The flowers have white petals and

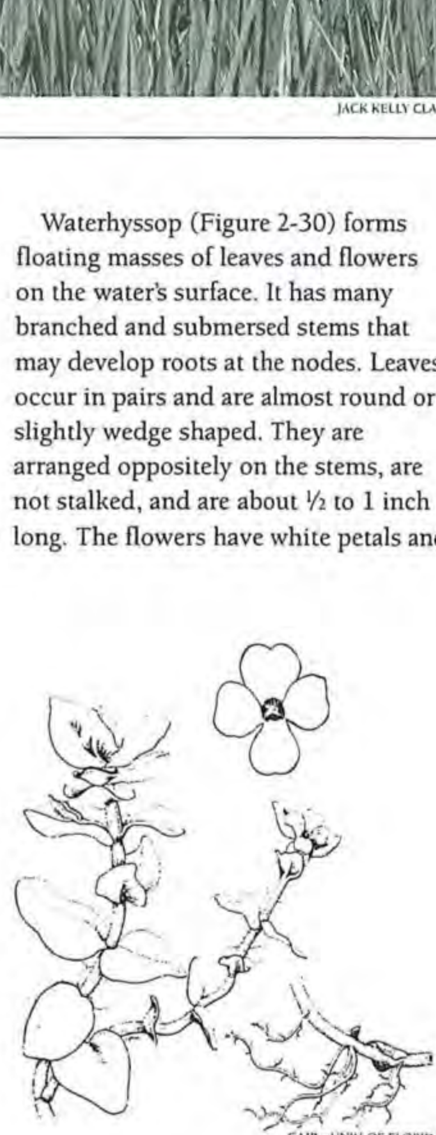

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FIGURE 2-30.
Waterhyssop.

FIGURE 2-31.
Waterprimrose.

a yellow center. Two waterhyssops are common in California rice fields: Eisen waterhyssop (*B. eisenii*), and disc waterhyssop (*B. rotundifolia*). Eisen waterhyssop has showy flowers almost as large as the leaves, while the flowers of disc waterhyssop are smaller.

Waterprimrose (*Ludwigia* spp., Evening Primrose family). **Life cycle:** Annual and perennial. **Habitat:** Shallow marshy areas, wet meadows, pond margins, pits, ditches, lake margins, stream banks, shorelines, and swamps.

Waterprimrose (Figure 2-31) has branched stems and yellow flowers with four or five petals, and can grow up to 6 feet tall. The stems sometimes have long hairs, and tiny soft hairs cover both sides of the leaves, which are oval to lance shaped. The leaves are up to 6 inches long. *L. repens* is commonly called floating waterprimrose.

SUBMERSED AQUATIC WEEDS

Submersed aquatic weeds generally live beneath the water's surface and are supported by the water. Most are rooted in the sediment. Leaves or flowers sometimes float on or emerge above the water's surface. Weed specialists divide this group into three subcategories: (1) rooted, without

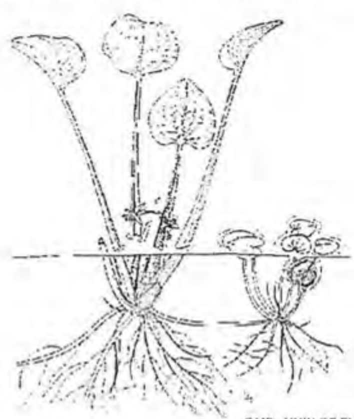

FIGURE 2-32.
American frogbit.

floating leaves; (2) rooted, with floating leaves; and (3) without roots.

Submersed, Rooted, without Floating Leaves

American frogbit (*Limnobium spongia*, Waterweed family). **Life cycle:** Perennial. **Habitat:** Occurs in many water types, including deep and shallow water.

American frogbit (Figure 2-32) is a floating or rooted plant that often produces dense mats. It has two growth forms. Younger, uncrowded plants have small, heart-shaped leaves that float on the water's surface. These younger leaves are bright green and shiny on top, while their undersides are reddish with a spongy texture. Older plants develop leaves that are held erect above the water's surface on long petioles.

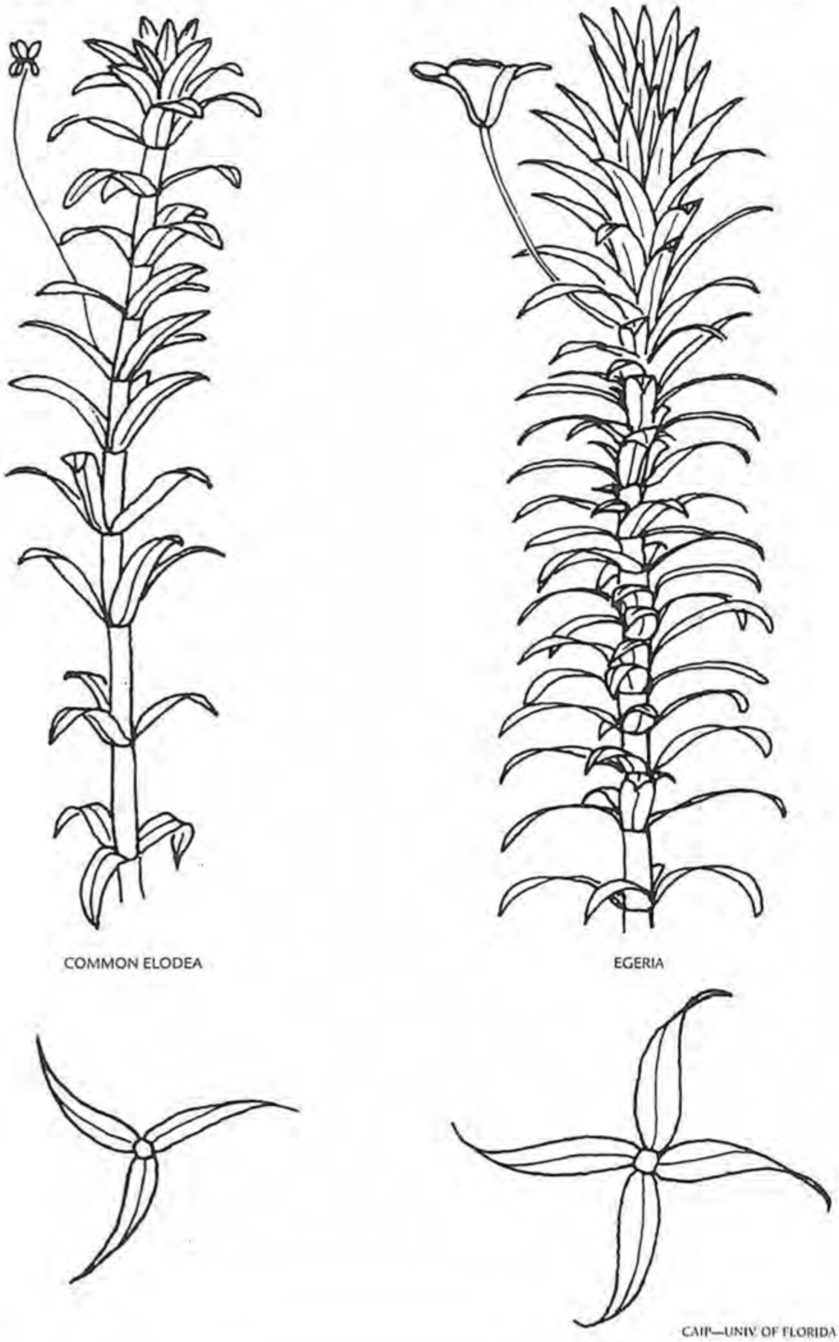

FIGURE 2-33.

Egeria (right) and comn

These leaves are also bright green, but they are rounded and the spongy tissue is absent. American frogbit flowers are borne on stalks that are one-third the height of adult leaf petioles. Flowers are silvery white and ½ to 1 inch across. American frogbit is sometimes confused with waterhyacinth (*Eichhornia crassipes*). However, the flowers of these two aquatic weeds make them easily distinguishable from each other, since waterhyacinth has large blue to violet flowers borne in spikes. Even when flowers are absent, American frogbit can be distinguished by its silvery roots and rhizomes. American frogbit reproduces by seed and rhizomes.

Egeria (*Egeria densa*, Waterweed family, also know as **Brazilian elodea**). **Life cycle:** Perennial. **Habitat:** Quiet water, lakes, ponds, sloughs, tidally influenced fresh waters, and slow to moderately flowing streams.

Egeria (or Brazilian elodea) is rooted in the sediment, forms dense mats just below the water surface (Figure 2-33), and may be confused with other members of the Waterweed family, especially hydrilla and common elodea. Egeria has long, slender, branched stems that usually reach 1 to 2 feet in length but can sometimes be much longer. The dark-green, lance-shaped leaves, which are ½ to 1½ inches long and about ⅕ of an inch wide, grow in whorls of four to eight at the stem nodes. Lower leaves are further apart, while upper leaves become more crowded toward the stem tip. Leaf margins are minutely serrated. Egeria's male and female flowers are produced on separate plants, and female flowers have not been known to occur in the United States. The male flowers are about 1 inch across, white, showy, and extend above the water surface. Reproduction is by broken stem sections, and small buds on broken stem sections can overwinter and reproduce the next season.

Common elodea (*Elodea canadensis*, Waterweed family). **Life cycle:** Perennial. **Habitat:** Quiet water, shallow water, ditches, sloughs, ponds, and lakes.

Common elodea (see Figure 2-33) forms dense, dark green mats below the surface of the water. The stems branch frequently, and a single plant can reach 10 feet in length. Male and female flowers occur on separate plants, though some flowers are bisexual. Lower leaves on the female plant are small, oval, and arranged oppositely. Upper leaves are oblong, arranged in whorls of three, and minutely toothed. Male plants have thinner, more linear leaves. Flowers on female plants protrude above the water surface on a slender stalk that is ¾ to 6 inches long, while male flowers reach the water surface on a slender stalk that is 4 to 8 inches long. Reproduction happens mainly vegetatively through fragmentation and overwintering buds. Common elodea lacks the small spines that occur on the lower midrib of hydrilla leaves.

Duck-lettuce (*Ottelia alismoides*, Waterweed family). **Life cycle:** Perennial. **Habitat:** Irrigation ditches, lakes, ponds, marshes, and rice fields. Particularly a pest in slow-moving or still bodies of water.

Duck-lettuce, which is on the Federal Noxious Weeds List, is uncommon in California. It roots in the sediment in water to 2 feet deep and has short, erect stems. Lower leaves are straplike, while floating or emersed leaves are wider and heart shaped. The plant's small flowers are white to pinkish with bright yellow anthers.

Eurasian watermilfoil (*Myriophyllum spicatum*, Watermilfoil family). **Life cycle:** Perennial. **Habitat:** Lake margins, ditches, ponds, streams, and estuaries, in fresh and brackish water; sometimes in water to 16 feet deep.

Eurasian watermilfoil (Figure 2-34) is rooted in the sediment and has

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FIGURE 2-34.
Eurasian watermilfoil.

branched stems that can reach lengths of 10 feet or more and that vary in color from reddish to brown. Clumps of the plant can break loose and form large floating mats. The 2-inch-long leaves grow in whorls of three or four per node and are subdivided into 6 to 16 segments on each side of the leaf. These segments are themselves each finely dissected, giving the plant a feathery appearance. Flowers grow in whorls of four on terminal stalks that are held above the water surface. Each flower has four petals. Eurasian watermilfoil is very adaptable to many different aquatic situations. It reproduces rapidly by seed, stem fragments, rhizomes, and turions, and it overwinters well in cool water.

Horned pondweed (*Zannichellia palustris*, Horned Pondweed family). **Life cycle:** Perennial. **Habitat:** Fresh or brackish water; streams, ponds, ditches, and lakes. This native plant is an important species in native habitats.

Horned pondweed is completely submersed, forming dense, usually short masses of vegetation. Smooth-margined, narrow, threadlike leaves grow oppositely on erect, sparsely branched stems. The plant produces flowers and fruit in the leaf axils. The flowers are inconspicuous, and the fruit are flat with a beak at the end. Horned pondweed reproduces by seed.

Hydrilla (*Hydrilla verticillata*, Waterweed family). **Life cycle:** Perennial. **Habitat:** Most types of water bodies, including ditches, canals, ponds, reservoirs, and lakes. It has been found growing as deep as 50 feet in rivers in the United States. Hydrilla (Figure 2-35) is on the Federal Noxious Weeds List. Figure 2-36 is a map showing hydrilla infestations in California.

Hydrilla roots in the sediment, growing at depths of 35 to 50 feet to just below the water surface. F fragments can break off and form large floating mats. Hydrilla's slender, much-branched stems may grow up to 25 feet long, and the weed has coarsely serrated, lance-shaped leaves that are about 1/8 inch wide and 1/2 inch long. The midvein of the leaves is red and has at least one spine on the lower surface. Leaves are arranged in pairs lower down on the plant and in whorls of two to eight higher up. Because of the serrated, spiny leaves, hydrilla feels very rough when you draw it through your hand, which is a good way to distinguish it from egeria. Hydrilla has small, inconspicuous flowers borne singly on threadlike stems that extend to the water surface. The flowers have three white petals. In California, plants may have male and female flowers on the same plant, or female flowers only. Hydrilla reproduces vegetatively from pealike tubers and from winter buds that grow in the leaf axils. It also produces extensive rhizomes and

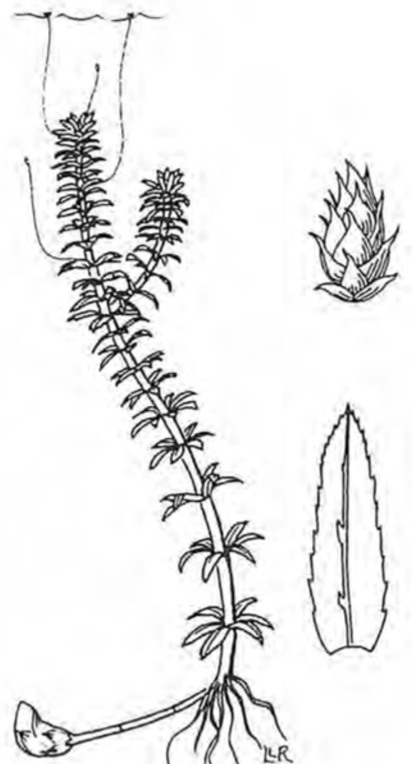

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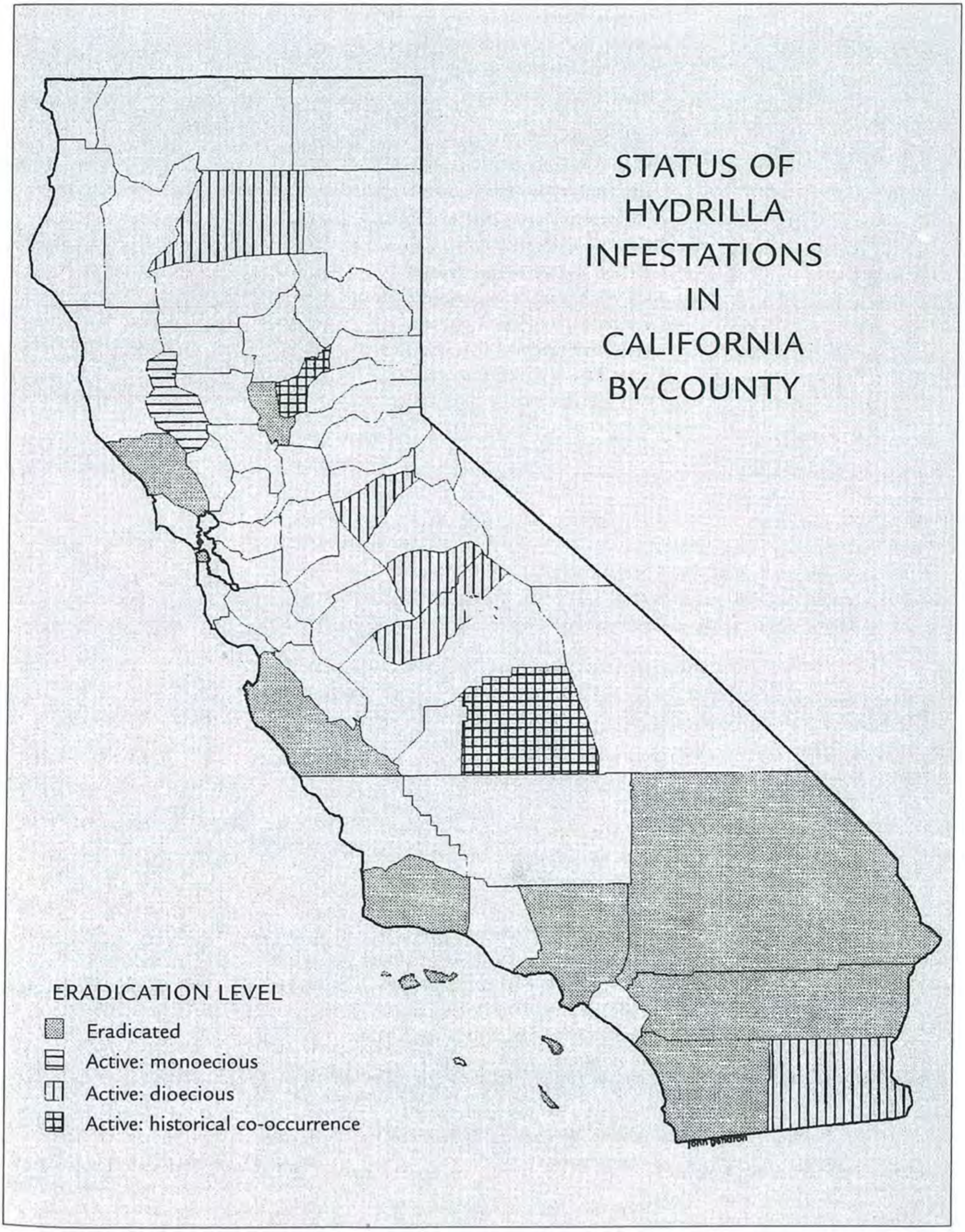
FIGURE 2-35.

ydrilla.

FIGURE 2-36.

Status of hydrilla *infestation in California as of 1999 (California Department of Food and Agriculture Noxious Weed Information System data).*



stolons, from which stems arise. Also, plant fragments can produce new plants. These multiple means of reproduction, combined with hydrilla's adaptability to practically any aquatic environment, make this weed extremely difficult to control.

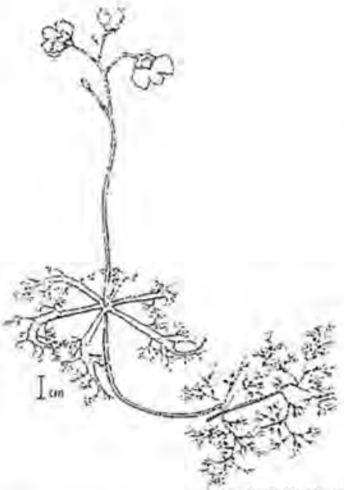


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FIGURE 2-37.
Bladderwort.

Bladderwort (*Utricularia* spp., Bladderwort family). **Life cycle:** Perennial. **Habitat:** Ponds, lakes, swamps, slow-moving streams with mucky or sandy bottoms.

All 200 species of bladderworts (Figure 2-37) are distinguished by tiny bladders that trap and digest minute aquatic invertebrates. These bladders are attached at regular intervals to the leaves, which are thin, finely dissected, and scattered along the stems. Bladderwort flowers, usually yellow but sometimes purple, have two liplike petals and arise on long flower stalks that extend above the water's surface.

Naiad (*Najas* spp., Waterweed family). **Life cycle:** Annual. **Habitat:** Ponds, lakes, slow-moving streams, irrigation ditches, reservoirs, marshes, and rivers; often in deep water.

Naiads (Figure 2-38) have slender, much-branched stems and sometimes grow as mats. The leaves are about 1 inch long, very narrow with serrated margins, and grow in opposite pairs or in whorls of three. Southern naiad (*Najas guadalupensis*) has extremely narrow leaves less than 1/16 inch wide, and a hand lens is needed to see the teeth on the leaf margins. Brittleleaf naiad (*Najas minor*) has long, pointed, spiny leaves, and the entire plant is brittle and breaks easily. This naiad may be confused with the algae *Chara* spp. However, *Chara* spp. have a musky odor when crushed, whereas brittleleaf naiad does not. Naiads reproduce by seed and vegetatively by broken stem sections.

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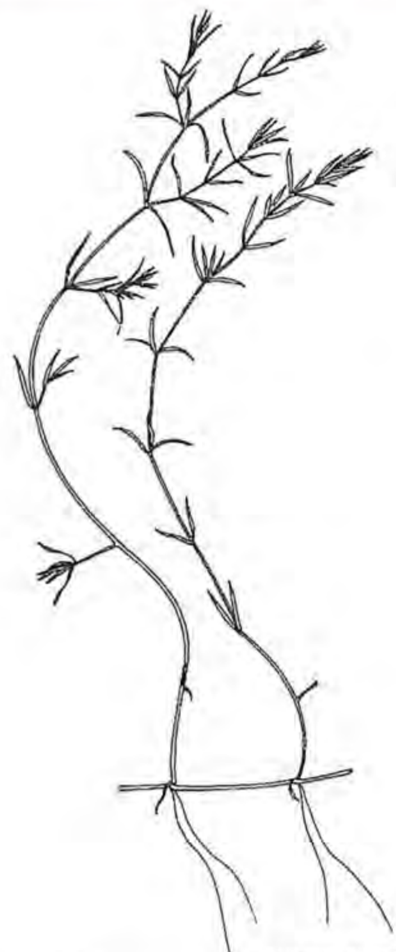

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FIGURE 2-38.
Naiads can be very troublesome. The photo at top shows the spinyleaf naiad, Najas maritima, *and the drawing is of the Southern naiad,* Najas guadalupensis.

Parrotfeather (*Myriophyllum aquaticum*, Watermilfoil family). **L**

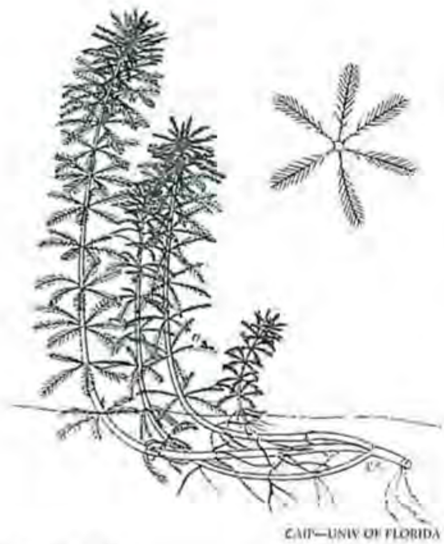

FIGURE 2-39.
Parrotfeather.

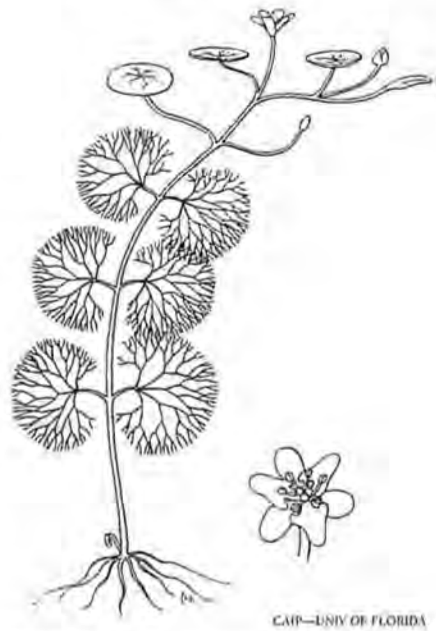

FIGURE 2-40.
Purple fanwort.

cycle: Perennial. **Habitat:** Lakes, ponds, canals, ditches, and slow-moving streams.

Parrotfeather (Figure 2-39) has both emersed and submersed characteristics and can be classified as either. It has unbranched stems that trail horizontally, becoming erect at the end. The erect portion of the stem extends as much as 8 inches above the water surface. Submersed and emersed leaves are green, oblong, and grow in whorls of four to six leaves that each give rise to 6 to 18 pairs of threadlike segments. This gives the leaves their feathery appearance. The emersed leaves have a waxy coating. Parrotfeather flowers are inconspicuous.

Purple fanwort (*Cabomba caroliniana*, Watershield family). **Life cycle:** Perennial. **Habitat:** Slow-moving streams, ponds, and lakes in warm regions, generally in 3 to 10 feet of water.

Purple fanwort (Figure 2-40) has slender, much-branched stems that are up to 6 feet long and that may have a thin gelatinous coating. The plant has two kinds of leaves. The olive-green submersed leaves grow oppositely or whorled and are finely dissected and fan shaped. The brighter green, floating leaves are narrow, less than 1 inch long, and are constricted at the center where the leaf joins the petiole. Flowers are white to pink or purplish and arise from the axils of the upper leaves. Purple fanwort reproduces by seed and by vegetative fragmentation.

Pondweeds

The pondweed family includes about 80 species worldwide. Although all are submersed, they have differing characteristics. Some pondweeds have narrow, threadlike or ribbonlike leaves, and others have broad leaves. Some, such as American pondweed, have both underwater and floating leaves, and these differ from each other in form. Stems vary from upright to horizontal and from a few inches to several feet long. Flowers are usually greenish or brownish and are small and grow in spikes. Some of the pondweed species that lack floating leaves are described below, while some of the species that have floating leaves are described in the next section.

Curlyleaf pondweed (*Potamogeton crispus*, Pondweed family). **Life cycle:** Perennial. **Habitat:** This introduced plant inhabits ponds, lakes, irrigation canals, and streams.

Curlyleaf pondweed (Figure 2-41) has leaf margins that are finely-toothed and that, upon maturity, become wavy or curly. The somewhat flattened stems freely branch on the upper portions of the plant. Reproduction is through stem sections and turions. At maturity turions fall to the sediment, where they develop in the subsequent growing season.

Leafy pondweed (*Potamogeton foliosus*, Pondweed family). **Life cycle:** Perennial. **Habitat:** This native plant is found in shallow water, ponds, lakes, streams, and irrigation ditches.

Leafy pondweed is completely submersed and produces extensive foliage. Its leaves are very narrow (less than 1/8 inch wide) and flat with a definite midvein that is white or yellowish. The plant develops dense mats of slender rhizomes just below the surface of the sediment, rooting at each node. The erect stems grow to varying lengths, depending on the depth of the water. Flowers and fruiting spikes are produced on short stems that arise from the ends of the plant's erect main stems.

Richardson's pondweed (*Potamogeton richardsonii*, Pondweed family). **Life cycle:** Perennial. **Habitat:** Shallow to deep water, ponds, lakes, lagoons, reservoirs, irrigation ditches, and streams, often in water up to 20 feet deep. This native plant is often found in patches or beds.

Richardson's pondweed is characterized by wide, wavy leaves that have a broad base that extends three-quarters of the way around the stem, clasping it. Often confused with curlyleaf pondweed, Richardson's pondweed has smooth leaf margins, while curlyleaf pondweed has serrated margins. All growth is below the water surface except for the flowers, which are borne on spikes and may emerge above the surface. Nutlike fruit are produced on the flower spikes. Vegetative reproduction is from rhizomes.

Sago pondweed (*Potamogeton pectinatus*, Pondweed family). **Life cycle:** Perennial. **Habitat:** This native plant inhabits shallow water, ponds,

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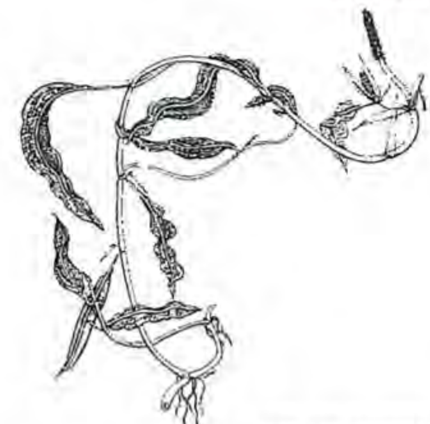

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FIGURE 2-41.

Curlyleaf pondweed.

FIGURE 2-42.

Sago pondweed (by permission of the University of California Press, from Mason, H., Flora of the Marshes of California, *1957).*

FIGURE 2-43.
Small pondweed.

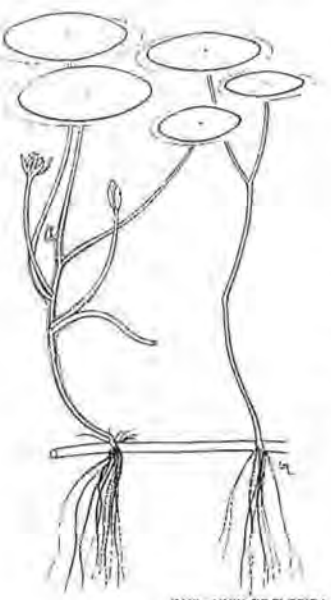

FIGURE 2-44.
Watershield.

lakes, streams, and irrigation ditches. It is found in fresh, saline, or brackish waters.

Sago pondweed (Figure 2-42) is characterized by highly branched vegetative growth, with slender stems and very narrow leaves arranged in an overall fan-shaped order. The leaves, always submersed, are somewhat triangular in cross-section, and the leaf tip is long, tapering to a point. Flowers and nutlike fruit arise from a long, slender terminal stem that floats at or near the water surface. Reproduction is primarily by tubers or fragmentation of vegetative plant parts and occasionally by seed.

Small pondweed (*Potamogeton pusillus*, Pondweed family). **Life cycle:** Perennial. **Habitat:** A native plant found in shallow water, ponds, lakes, reservoirs, ditches, vernal pools, and slow-moving streams.

Small pondweed (Figure 2-43) is characterized by very thin, straplike leaves that are arranged alternately along the stems. The stems are deep green, slender or threadlike, and much-branched. Small pondweed's flowers appear in whorls on spikes up to 3/4 inch long, and the flower spikes are borne on stalks up to 2½ inches long. Reproduction is from seed and turions.

Watershield (*Brasenia schreberi*, Watershield family). **Life cycle:** Perennial. **Habitat:** A native plant found in ponds, lakes, swamps, ditches, and slow-moving streams, usually in water up to 6 feet deep.

Watershield (Figure 2-44) is distinguished by oval to elliptical leaves ("shield" shaped) that range from 2 to 5 inches in diameter and float on the water's surface. They are green on top and purple underneath and have no lobes, and the leaf stem attaches at the center of the leaf. The underside of the leaves and the submersed stems are coated with a thick layer of jellylike material. Watershield produces dull purple flowers in early summer. Reproduction is from rootstocks.

Widgeongrass (*Ruppia maritima*, Pondweed family). **Life cycle:** Perennial. **Habitat:** Ponds, marshes, sloughs, streams, ditches, canals, and estuaries. This native grows mainly in saline or brackish waters.

Widgeongrass has much-branched stems and threadlike leaves with smooth margins. Its flowers are inconspicuous and are borne in pairs from the leaf sheath. The fruit are fleshy and are usually clustered four to six together on a slender stalk. The plant has an extensive root system under the sediment.

Submersed, Rooted, with Floating Leaves

Submersed, rooted plants with floating leaves include the waterlilies, some of the pondweeds, and other familiar species.

American lotus (*Nelumbo lutea*, Lotus family). **Life cycle:** Perennial. **Habitat:** Muddy, shallow areas of ponds and lakes and slow-moving streams and rivers; marshes. This plant is not found in California.

American lotus (Figure 2-45) has very large leaves (up to 2 feet in diameter) that extend above the water's surface at maturity. Leaves produced

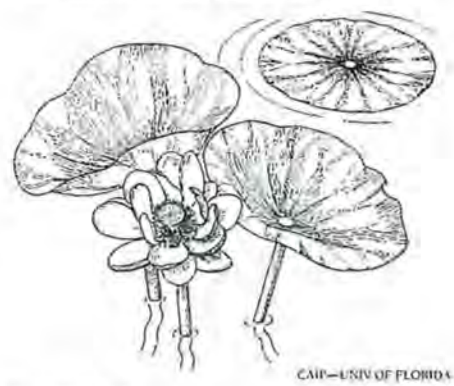

FIGURE 2-45.
American lotus.

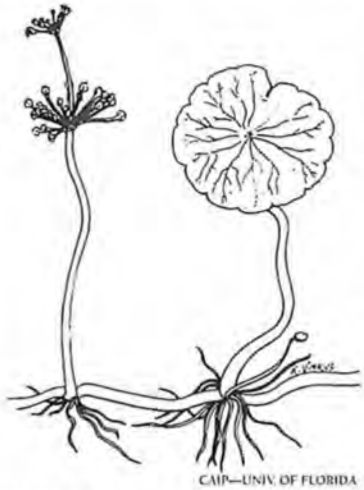

FIGURE 2-46.
Floating pennywort.

earlier in the season lie on the water's surface. The petiole is attached in the center of the completely circular, often cup-shaped leaves. The American lotus leaf has no split, and this distinguishes it from waterlily. It produces large, yellowish-white flowers with more than 20 petals and sepals, and later a large, top-shaped seed pod. American lotus has an extensive underground root system and reproduces by seed and rootstock.

Floating pennywort (*Hydrocotyle ranunculoides*, Carrot family). **Life cycle:** Perennial. **Habitat:** A California native found in and near ponds, lakes, rivers, and marshes.

Floating pennywort (Figure 2-46) has round, bluntly toothed, slightly to deeply lobed leaves that arise on a long petiole attached to the center of the blade. Each node of the underwater or underground creeping stems gives rise to a single leaf that can be up to 2¾ inches in diameter. Floating pennywort has small white flowers that appear in *umbels* and are borne on stalks that can be as tall as the leaves. Reproduction is by seed and creeping stems. Floating pennywort grows from the shoreline onto the water as a floating mat that may break loose from the shore and continue to grow.

White waterbuttercup (*Ranunculus aquatilis*, Buttercup family). **Life cycle:** Perennial. **Habitat:** This native plant is found in fresh or brackish water, lakes, ponds, marshes, ditches, and slow-moving streams.

White waterbuttercup is distinguished by hollow stems that support tufts of finely dissected, threadlike leaves that collapse upon removal from the water. Stems root at the lower nodes. The small, five-petaled flowers are white or yellow and bloom at the water's surface.

Pondweeds

Pondweeds that have floating leaves include American, floatingleaf, largeleaf, and variable pondweeds, among others.

American pondweed (*Potamogeton nodosus*, Pondweed family). **Life cycle:** Perennial. **Habitat:** Shallow water, lakes, ponds, ditches, and streams. It can also grow in swiftly running or deep water.

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FIGURE 2-47.
American pondweed.

American pondweed (Figure 2-47) has submersed leaves that are very narrow and linear in shape and floating leaves that are large and elliptical. The flowers are borne on a spike that emerges above the water. American pondweed spreads and reproduces by rhizomes and seed.

Floatingleaf pondweed (*Potamogeton natans*, Pondweed family). **Life cycle:** Perennial. **Habitat:** Shallow fresh or brackish water, lakes, ponds, bogs, marshes, lagoons, and streams.

Floatingleaf pondweed has elliptical floating leaves that are slightly heart shaped at the base. Its submersed leaves are long and narrow or absent, and it spreads by rhizomes.

Largeleaf pondweed (*Potamogeton amplifolius*, Pondweed family). **Life cycle:** Perennial. **Habitat:** Deep, clear-water lakes.

Largeleaf pondweed's floating leaves are large and elliptical in shape, and the submersed leaves are oblong, wavy, partially folded, and taper to the stem. The plant produces a solid, tightly packed spike of nutlets at its tip. Reproduction is by rhizomes.

Variable pondweed (*Potamogeton gramineus*, Pondweed family). **Life cycle:** Perennial. **Habitat:** Shallow water, ponds, lakes, and bogs.

This pondweed has grasslike submersed leaves, oval floating leaves, and reproduces from rhizomes.

Waterlilies

Waterlilies are rooted aquatic plants with floating leaves and showy flowers. Leaf size and the color of the flowers depend on the species.

Fragrant waterlily (*Nymphaea odorata*, Waterlily family). **Life cycle:** Perennial. **Habitat:** Slow-moving streams, ponds, and edges of lakes. It colonizes shallow water up to depths of 6 feet and dominates shorelines of shallow lakes.

Fragrant waterlily (Figure 2-48) has leaves that arise from rhizomes on long stems that are attached at the center of the leaf blade. The circular floating leaves generally lie flat on the water's surface and are split to the center. The blades are 2 to 10 inches in diameter, green on top, and purplish on the bottom. Fragrant waterlily's flowers , which open only in the morning hours, are white, 2 to 6 inches wide, very aromatic, and are borne singly a little above the water's surface on the end of a long stalk. Reproduction is by seed and rootstocks.

Mexican waterlily (*Nymphaea mexicana*, Waterlily family). **Life cycle:** Perennial. **Habitat:** Lakes, ponds, slow-moving streams, canals, irrigation ditches, and other waterways. Native to Southern California, the southeast United States, and Mexico.

Mexican waterlily has bright yellow flowers, tubers that are often erect, and

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FIGURE 2-48.
Fragrant waterlily.

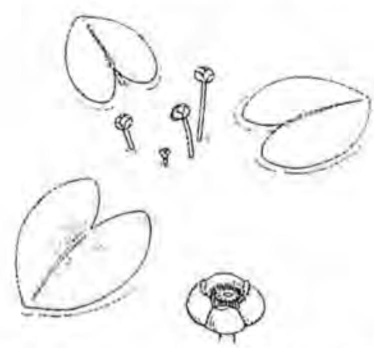

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FIGURE 2-49.
Spatterdock

deeply-notched floating leaves that are oval or round.

Spatterdock (*Nuphar* spp., Waterlily family). **Life cycle:** Perennial. **Habitat:** Swamps, lakes, ponds, and slow-moving streams. Only the native *N. lutea* occurs in California.

Spatterdock (Figure 2-49), also known as yellow pondlily or cowlily, has large, heart-shaped leaves with a conspicuous midvein. The leaves sometimes float when young or at periods of high water, but more often they extend above the water's surface on petioles that attach at the bottom of the leaf, between the lobes. The flowers are ball shaped and 1½ to 2 inches in diameter, with thick petals that curve inward. They are borne at the end of a long, erect stalk rising above the surface of the water. The plant has thick, long rhizomes (2 to 12 inches long), and reproduces by seeds and rootstocks.

Submersed, without Roots, without Floating Leaves

The final category of submersed aquatic plants includes those that have neither roots nor floating leaves.

FIGURE 2-50.
Coontail.

Coontail (*Ceratophyllum demersum*, Hornwort family). **Life cycle:** Perennial. **Habitat:** Ponds, lakes, ditches, standing water, and slow-moving streams.

Coontail (Figure 2-50), a native in California, has dark green leaves arranged in whorls on branched, flexible, cordlike stems up to 31 inches long. Intervals between leaf whorls are closer toward the tip, giving the appearance of a bushy tail. Leaves are forked and have jagged projections on the margins. Each leaf also has several small teeth on the midrib. These make the plant feel rough if you run it through your hand. Very small, inconspicuous flowers are produced in the axils of the leaf whorls. The flowers are rarely seen. Reproduction is by seed and by stem sections that break loose from the parent plant. Coontail can be confused with some watermilfoils, purple fanwort, and *Chara* spp. Familiarize yourself with their differences using this manual's descriptions of these weeds.

FREE-FLOATING AQUATIC WEEDS

The last group of aquatic weeds to be described are those that float freely on the water surface. These weeds usually have roots, but their roots usually do not attach to anything.

FIGURE 2-51.
Waterhyacinth.

Waterhyacinth (*Eichhornia crassipes*, Pickerelweed family). **Life cycle:** Perennial. **Habitat:** Lakes, slow-moving streams, ponds, sloughs, waterways, ditches, and backwater areas.

Waterhyacinth (Figure 2-51) is considered one of the world's most troublesome aquatic weeds. It spreads vegetatively by stolons that root at the nodes, producing new plants that develop into mats covering large areas. It also reproduces by seed that can remain dormant for more than 10 years until conditions favor germination. Plant size varies, extending a few inches to 3 feet above the water. The large, oval to round leaves are bright green, shiny, and smooth. Leaf stalks are usually very bulbous, filled with spongy tissue that makes them act as floats. Roots are dark-colored, fibrous, and hang underwater beneath the plants in a mass. Waterhyacinth's showy flowers are borne in spikes and are light blue to violet with a yellow marking on the upper portion of the uppermost petal. Waterhyacinth is a major aquatic pest in the Sacramento-San Joaquin River Delta.

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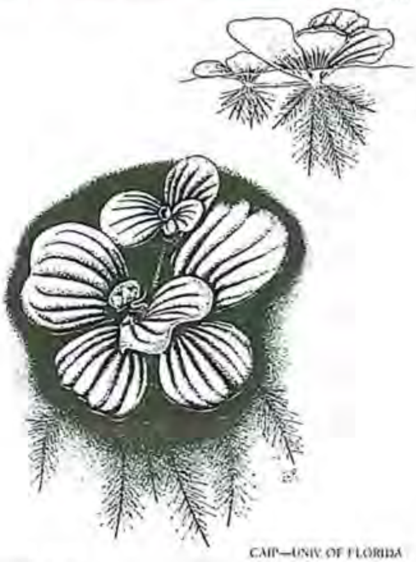

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FIGURE 2-52.
Waterlettuce.

Waterlettuce (*Pistia stratiotes*, Arum family). **Life cycle:** Perennial. **Habitat:** Ponds, lakes, canals, and slow-moving rivers and streams.

Watterlettuce (Figure 2-52) is a free-floating weed that sometimes forms large mats. It has light yellow-green, spongy, inflated leaves that grow in a *rosette* and have soft hairs on both sides of the blade. Plants have a tuft of long, unbranched, fibrous roots extending from an underwater rhizome. The leaves do not have stalks, are strongly veined, and can be up to 20 inches long. Mature plants produce a large number of small, inconspicuous flowers in the center of the plant. Most reproduction occurs vegetatively by buds, since seed production is very limited when it occurs at all.

Duckweed and Watermeal

Duckweeds thrive in still or slow-moving fresh watercourses, especially those rich in nutrients. They multiply very rapidly, forming large floating mats, and can completely cover the surface of a small pond or canal in a matter of days. Some duckweeds are the smallest of flowering plants, though flowers are seldom seen and some species never flower. Duckweeds are distinguished by their extremely small size and lack of stems and true leaves. The body of the plant is a leaflike structure called a frond, that floats on the water's surface. Plants in the duckweed family (including watermeal) propagate vegetatively by prolific budding of new individual plants from the edge or base of parent

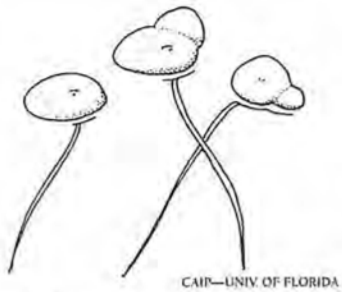

FIGURE 2-53.
Common duckweed.

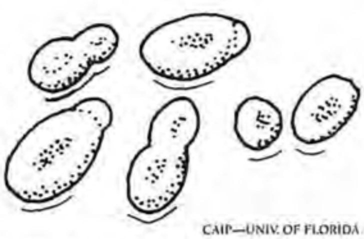

FIGURE 2-54.
Common watermeal.

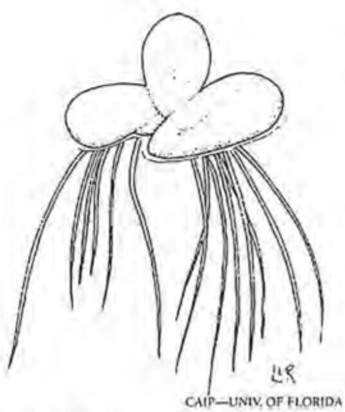

FIGURE 2-55.
Giant duckweed.

fronds. Duckweeds overwinter both by seed and by a tiny bulblet frond that sinks to the bottom of the body of water and rises to the surface the following season.

Common duckweed (*Lemna minor*, Duckweed family). **Life cycle:** Perennial. **Habitat:** Still or slow-moving fresh water.

Common duckweed (Figure 2-53) fronds are tiny (pinhead sized), oval to round, and glossy green. They are generally attached in groups of two individuals (and sometimes up to eight) because of their vegetative mode of reproduction. A single root extends from a small pouch on the lower surface of each frond. Common duckweed often grows together with watermeal, and the two can create a layer of plants 1 to 2 inches thick on the water's surface.

Common watermeal (*Wolffia* spp., Duckweed family). **Life cycle:** Perennial. **Habitat:** Still or slow-moving fresh water.

Common watermeal (Figure 2-54) is the smallest of all flowering plants, with two species native in California. Its individual plants are spherical and are so tiny that they look like minute green seeds. The plants are transparent and lack roots. Common watermeal feels grainy, like cornmeal, if you rub a handful between your fingers. The plants generally float on the water's surface. Reproduction is chiefly by vegetative budding, and the plants are capable of lying dormant on rather dry soil along shorelines until water is available to make them grow again. Common watermeal is extremely difficult to control.

Giant duckweed (*Spirodela polyrhiza*, Duckweed family). **Life cycle:** Perennial. **Habitat:** Still or slow-moving fresh water. A California native.

Giant duckweed (Figure 2-55) has round to oval fronds that are less than 5/16 inch long but tend to be larger than the fronds of common duckweed. Giant duckweed's fronds have seven to twelve visible veins and are dark green on the upper surface and purple-red on the lower surface. Four to nine small roots extend from the lower surface of each frond. Colonies of two or more leaves attached together occur as a result of reproductive budding.

Free-Floating Water Ferns

Many ferns can be found in wetland habitats and along shorelines, but there are only two truly aquatic ferns in California that the aquatic pest manager will encounter and need to control: mosquitofern and salvinia.

Mosquitofern (*Azolla* spp., Mosquitofern family). **Life cycle:** Perennial. **Habitat:** Ponds and swamps, floating on water or stranded on mud.

Mosquitofern (Figure 2-56) is a small, floating fern with lobed leaves that are less than 1/32 inch long. The leaves overlap closely to form mats up to 20 inches across, while individual plants are approximately 1/4 to 1/2 inch wide. The upper lobe of each leaf sticks

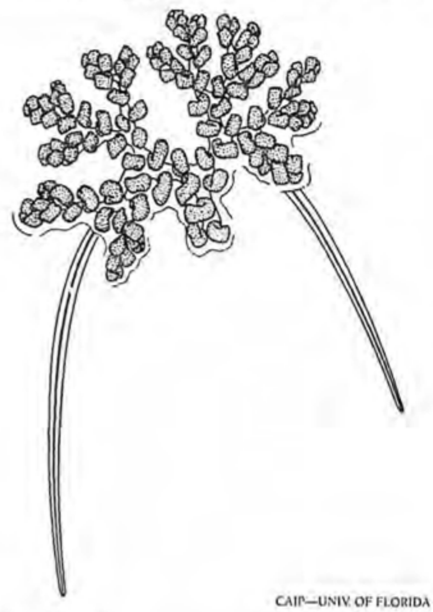

FIGURE 2-56.
Mosquitofern.

up above the water, and the lower lobe is submersed. Leaves may be green, brownish-red, or red. Inconspicuous rootlets are borne on the undersurface of the leaves. The lower leaf surfaces of upper leaf lobes have cavities in which a species of the blue-green algae genus *Anabaena* lives in abundance. The relationship between this *Anabaena* species and mosquitofern results in nitrogen fixation. Mosquitofern reproduces by spores and by vegetative budding of leaves that break away from the plant. The plant often grows in association with duckweed. *A. filiculoides* is the most common species in California.

Salvinia (*Salvinia* spp., Water fern family). **Life cycle:** Perennial. **Habitat:** Stagnant or slow-flowing water, ponds, canals, small bays, and estuaries of small streams; grows best in water high in organic matter.

Salvinia (Figure 2-57) is a free-floating fern with two kinds of leaves. Those that extend above the water's surface are bright green and about 3/4 inch in diameter. These leaves are folded at the midrib and positioned in pairs along the stem. The upper surfaces of the leaves are covered with stalks that branch into two or more hairs. In *Salvinia molesta,* these hairs rejoin at the tips, forming distinct eggbeater-like structures. This distinguishes *S. molesta* from common salvinia, *S. minima,* in which branched hairs remain separated at the tips.

Salvinia also has hanging, submerged leaves that are finely dissected and look like roots. Because of branching, individual salvinia plants can be up to 6 inches in diameter. Though salvinia produces spores, propagation is mainly by vegetative means. This weed can readily form mats that are as much as 1 foot thick and that completely cover water surfaces. The species *S. molesta* is the plant of greatest concern in California.

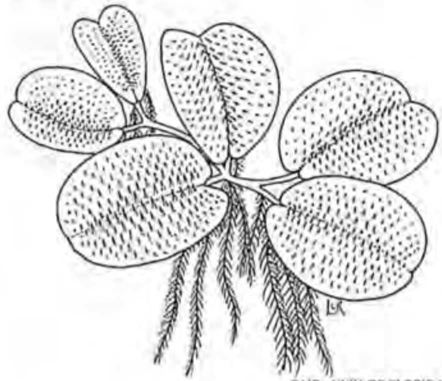

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FIGURE 2-57.

Salvinia (top). On the upper leaves of S. molesta, *stalks branch into hairs that rejoin at the tips to form distinct eggbeater-like structures (bottom).*

REVIEW QUESTIONS

(answers on page 145)

1. The first step in aquatic weed control is to:

- ☐ a. Determine whether the weeds are algae, emersed, submersed, or free-floating
- ☐ b. Identify the weeds to be controlled
- ☐ c. Determine whether the weeds are mostly monocots or dicots
- ☐ d. Read the labels of herbicides you plan to use

2. Monocots are usually:

- ☐ a. Narrow-leaved plants such as grasses, sedges, and rushes
- ☐ b. Broadleaf plants such as waterlily, American lotus, Eurasian watermilfoil, and parrotfeather
- ☐ c. Plants with leaf veins that branch and are netlike
- ☐ d. Plants with one leaf

3. Which of the following is *not* true:

- ☐ a. An annual weed completes its life cycle in 1 year
- ☐ b. A biennial weed completes its life cycle in 2 years
- ☐ c. A perennial weed completes its life cycle in 3 or more years
- ☐ d. A biennial weed flowers every other year

4. Algae reproduce by:

- ☐ a. Seed and flowers
- ☐ b. Rhizomes
- ☐ c. Cell division, fragmentation, or spores
- ☐ d. Tubers

5. Planktonic algae can color the water green, bluish-green, yellowish-green, red, or brown in an overgrowth called:

- ☐ a. Scum
- ☐ b. Bloom
- ☐ c. Slime
- ☐ d. Toxic layer

6. The most common group of nuisance planktonic algae are:

- ☐ a. Yellow-green algae
- ☐ b. Red algae
- ☐ c. Brown algae
- ☐ d. Blue-green algae

7. Which of the following is *not* true of Charophytes:

- ☐ a. Like vascular plants, they have true roots, leaves, and flowers
- ☐ b. They are submersed and multicellular
- ☐ c. They have holdfast structures that anchor them to the sediment
- ☐ d. The most common are *Chara* and *Nitella*

8. Which aquatic plant has cylinder-shaped inflorescences?

- ☐ a. Alligatorweed
- ☐ b. Burhead
- ☐ c. Cattail
- ☐ d. Bulrush

9. Which of the following is *not* true about purple loosestrife?

- ☐ a. It has showy magenta flowers
- ☐ b. The flowers grow in spikes as long as 2 feet
- ☐ c. A single plant can produce over 2 million seed annually
- ☐ d. Most wildlife species use the plant for food or nesting

10. Brittleleaf naiad is often confused with:

- ☐ a. Fragrant waterlily
- ☐ b. Chara
- ☐ c. Horned pondweed
- ☐ d. Curlyleaf pondweed

11. Egeria differs from hydrilla in that it:

- ☐ a. Has branched stems
- ☐ b. Reproduces by plant fragments
- ☐ c. Can form large, dense mats
- ☐ d. Feels smooth when you draw it through your hand

12. The American lotus differs from waterlily in that the American lotus:

- ☐ a. Has large, round leaves that have a split
- ☐ b. Has leaves that float on the surface
- ☐ c. Does not produce flowers
- ☐ d. Has large, round leaves that have no split

13. Which of the following is the smallest free-floating weed?

- ☐ a. Common duckweed
- ☐ b. Common watermeal
- ☐ c. Waterlettuce
- ☐ d. Waterhyacinth

3 Controlling Aquatic Weeds

CALIFORNIA DEPARTMENT OF BOATING AND WATERWAYS

Aquatic weed harvesters, such as this one working in the Sacramento-San Joaquin Delta, are useful for controlling many types of aquatic weeds.

Control measures for aquatic weeds are usually necessary if the weeds

- restrict recreational, agricultural, industrial, or navigational activities
- impact fish populations
- degrade water quality
- lower waterfront property values
- harbor disease-carrying vectors such as mosquitoes

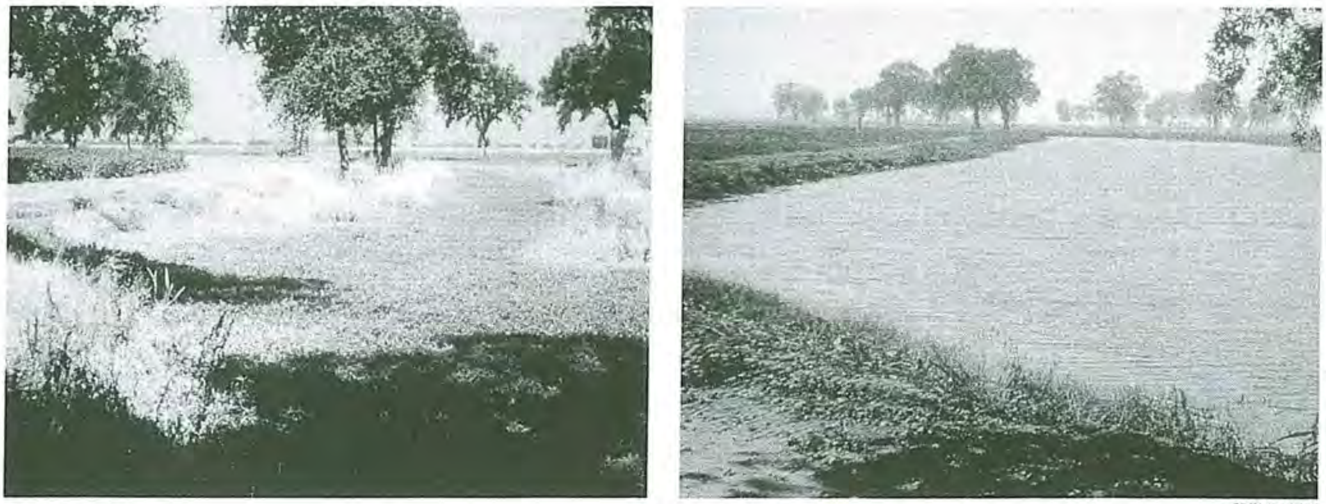
Managing weeds in the aquatic environment involves selecting and carefully using one or more management methods—chemical, mechanical, cultural, and biological. Of the four methods, chemical control is the most frequently used, because herbicides usually are an economical way to quickly and thoroughly control most aquatic weeds. For instance, Figure 3-1 shows an alligatorweed infestation before and after an herbicide application.

CHEMICAL CONTROL

Most aquatic herbicides require about 10 years of development and testing by their manufacturers before they are ready to be registered by the U.S. Environmental Protection Agency (EPA). The herbicides must not only control specific aquatic weeds but must meet rigid environmental standards and toxicological criteria.

By 2000, there were approximately 200 herbicide active ingredients registered for use in the United States, but less than a dozen of these were labeled for use in aquatic settings. Aquatic herbicides are few in number because the aquatic environment is unique and only certain compounds are considered safe and effective enough to be used there.

To be effective, aquatic herbicides must be taken up by target weeds within a reasonable time and in sufficient amounts to achieve adequate



CDFA PHOTOS

FIGURE 3-1.

Alligatorweed infestation before treatment (left) and after an herbicide application (right).

FIGURE 3-2. JACK KELLY CLARK

Aquatic herbicides are usually applied in mid-spring through early summer when plant growth is most vigorous and when there is less mass to treat.

control. Proper use of the herbicide must not harm the environment, people, and other nontarget organisms.

Aquatic herbicides are usually applied from mid-spring through early summer when weed growth is most vigorous yet there is less mass to treat (Figure 3-2). When planning aquatic weed control with herbicides, it is important to

- identify the weeds
- define the goals of your control efforts (boundaries of the treatment area, eradication versus suppression, long- or short-term control)
- understand the current and ultimate uses of the water being treated
- know the water characteristics, including temperature, alkalinity, and flow rate
- measure the volume of water and the size of the infested area
- choose the appropriate herbicide and application rate for existing conditions (weather, environmental constraints, protection of people and wildlife, ultimate uses of the water)
- calculate the dosage based on the volume or area to be treated
- select the appropriate treatment time (based on weather conditions and use patterns to reduce exposure to people, wildlife, and *beneficials*)
- choose a suitable application method (spot treatments, shoreline applications, watercraft, or aircraft; surface sprays, bottom applications, or injections for flowing water)

Advantages of Chemical Control

Herbicides used to control aquatic weeds are usually easy to apply, convenient, and provide effective and rapid control. Herbicides generally are the most cost-effective control method, and you can use them in a variety of situations. Some have selective characteristics so you can remove target pests without harming other plant species. In certain control efforts, these herbicides have the least environmental impact of any method.

Disadvantages of Chemical Control

Using herbicides to control aquatic weeds also has specific disadvantages:

- Some herbicides may be hazardous to people and the environment if you fail to handle or apply them properly.
- You must receive special training and apply herbicides in compliance with all laws and regulations.
- You must accurately measure the target area, correctly measure the herbicides, and carefully time applications.
- Like other control methods, aquatic herbicides frequently do not provide permanent control; you may need to repeat applications when weeds reappear.
- Long-term use of certain herbicides may lead to resistance.
- Certain herbicides may temporarily or permanently injure nontarget plants.

Properties of Herbicides

For comparison, herbicides are grouped according to their chemical similarities and herbicidal properties. These properties include absorption characteristics, selectivity, and physiological processes affected within target plants.

Absorption Characteristics

Herbicides kill weeds either by destroying the plant tissues that they directly contact (contact herbicides), or by moving through the plant to a site, such as the roots, where they disrupt normal plant functions (systemic herbicides).

Contact Herbicides. Contact herbicides kill only the parts of the weed that are exposed to the herbicide, such as leaves and stems. They act rapidly and are typically more effective on annual plants than perennials. This is because perennials sprayed with contact herbicides may simply regrow from untreated plant parts (Figure 3-3). Examples of materials that have been used as contact herbicides include copper, endothall, and diquat. Copper products are selective for certain submersed aquatic weeds.

Systemic Herbicides. Systemic herbicides are moved internally throughout the plant or to specific

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FIGURE 3-3.

Perennial weeds, such as this waterhyacinth, may regrow from untreated plant parts after being sprayed with a contact herbicide.

TABLE 3-1.

*Broad Spectrum and Selective Aquatic Herbicides.**

Examples of Broad Spectrum Aquatic Herbicides	Example of Selective Aquatic Herbicides	Examples of Broad Spectrum Herbicides Used as Selective Herbicides
Glyphosate	2,4-D	Diquat
Diquat		Endothall
Endothall		Fluridone
Fluridone		Copper

*Broad spectrum herbicides are used to control all or most vegetation, while selective aquatic herbicides are used to control certain plants and not others. Some materials listed in this table may no longer be registered as pesticides or their uses may be greatly restricted. Always check current pesticide labels before making any pesticide application.

parts of the plant after being sprayed on leaf surfaces or being picked up by the roots. This process is called translocation. Examples of materials that have been used as systemic herbicides include 2,4-D, dichlobenil, fluridone, and glyphosate.

Systemic herbicides differ from contact herbicides in several ways. They act more slowly, are generally more effective for controlling perennial and woody plants, and may be more selective.

Selectivity

Selectivity refers to the ability of a specific herbicide to control certain types of plants without having an effect on other types of plants. Selectivity is primarily determined by the mode of action of the herbicide, but other factors may also be involved. Some herbicides, such as glyphosate, are not selective. These are effective on most types of emerged vegetation and are known as *broad spectrum* herbicides. Table 3-1 lists examples of both broad spectrum and selective chemicals that have been used as aquatic herbicides.

FIGURE 3-4. JACK KELLY CLARK

Systemic herbicides that translocate to the roots are usually quite effective when they are applied during the late and post-flowering stages. This is when plants are translocating materials to the roots for food storage. Note the long root system on this waterhyacinth.

Factors Influencing Selectivity. Factors that affect plant susceptibility to herbicides include the chemical nature of the active ingredient, the rate of application, how the material is applied, and the type of formulation. Other factors that influence how herbicides control some plants but not others include the physical characteristics of the plant, the ability of the herbicide to be translocated, and the stage of plant growth at the time of application.

Physical characteristics that affect selectivity include thick leaf cuticles and hairs that block the herbicide from entering plant tissues. Leaf shapes and angles can also affect the movement of herbicides into the plant. For example, broad, horizontal leaves, such as on waterlilies and waterlettuce, catch and retain more herbicide spray than narrow, upright leaves, such as those of bulrush and cattail. Sometimes adding certain adjuvants to the herbicide mixture improves the ability of the active ingredient to pass through the cuticle or waxy coating of leaves, contributing to the selective control of certain weeds.

Some systemic soil-applied herbicides are most effective on annuals that are in the early stages of growth. This is when food reserves are being transported upwards. Foliar-applied systemic herbicides are most effective on perennials during the late and post-flowering stages, when the plants are completing their growth cycle (Figure 3-4). During these stages, plants are translocating materials to the roots for food storage. Fall treatments of many aquatic weeds have proven very successful, often requiring a lower herbicide rate because of the higher plant translocation activity.

Physiological Processes Affected

The way that an herbicide destroys the target aquatic weed is known as its *mode of action*. In general, herbicides within a chemical class have the same mode of action on specific weeds. They may also have similar characteristics such as chemical structure, persistence in the environment, and types of formulations possible. Examples of modes of action include

- interfering with cellular respiration and metabolism
- inhibiting root and shoot growth
- blocking photosynthesis
- interfering with cell division
- destroying cell membranes
- inhibiting metabolism and protein synthesis

The mode of action often dictates when and how the herbicide is used. For instance, those that inhibit seed germination or seedling growth by interfering with cell division are used as preemergent herbicides, while types that destroy cell membranes are used as postemergent herbicides and are applied to the leaves of the growing plants.

Aquatic Herbicide Formulations

Herbicides used for controlling aquatic weeds are manufactured as *emulsifiable concentrates*, *wettable powders*, *water-soluble powders*, *aqueous solutions*, *flowables* or *aqueous suspensions*, *granules*, and *pellets*. The nature of the active ingredients or how the herbicide is to be applied usually dictates the type of formulation. Some active ingredients may not be soluble in water and therefore must be formulated as emulsions to allow them to be diluted with water and applied as sprays. Usually, a specific herbicide is available only in a single type of formulation.

Granules and pellets are broadcast over the area of water to be treated, and they sink to the bottom where they release the active ingredient directly into the rooting zone of target weeds. Pellets are uniform in shape and size and are usually larger than nonpelleted granulars. Because of their unvaried shape and size, pellets tend to provide more uniform coverage.

Except for granulars, the formulated herbicides are mixed and diluted with water before application. These formulations are used for controlling emersed and free-floating weeds by spraying them onto leaf surfaces. Also, some of these formulations are sprayed on, or directly metered into, the water or are injected beneath the surface (Figure 3-5).

Adjuvants

Adjuvants are materials that can be added to a pesticide mixture to improve the uptake of the herbicide or its ability to be applied. Manufacturers sometimes add such materials to herbicide formulations as part of the inert ingredients. These adjuvants improve the ability of active ingredients to mix with water, keep the formulation stable during storage, and make the product easier to apply. A detailed description of adjuvants and their uses is found in *The Safe and Effective Use of Pesticides, Second Edition.*

Because many herbicides already contain materials in their formulations that enhance coverage or penetration,

FIGURE 3-5.
Herbicides are injected beneath the water's surface to control submersed weeds.

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FIGURE 3-6.

Management of aquatic weeds in moving water requires knowledge of flow rate, total volume flow (cubic feet per second), and special application methods to maintain both the proper herbicide or algaecide concentrations and contact time.

it is often unnecessary to add other adjuvants to the spray tank. However, label directions may recommend using an adjuvant, such as a surfactant. To decide whether an adjuvant is needed, read the herbicide label. In California, adjuvants have specific registered uses, so be sure that any adjuvants you use are labeled for the type of aquatic site you are treating.

How Environmental Factors Affect Herbicide Activity

Environmental factors, including weather conditions, water movement, and the chemical characteristics of the water, often affect how well aquatic herbicides work.

Weather Conditions. Rainfall that occurs shortly after application can wash the herbicide off the leaves before it is absorbed into the target plants. Heavy rains also can wash away soil-applied herbicides from ditch banks. Bright sunlight and warm temperatures may degrade or dry up certain herbicides before they can be absorbed into the plants. Windy conditions during foliar applications will result in poor coverage. Cool temperatures slow plant growth, decreasing herbicide absorption and activity.

Water Movement. In order for an herbicide to be effective, it must be in contact with the target plants for a minimum amount of time. Flowing water can reduce this contact time and thereby reduce efficacy unless special application methods are used to maintain the proper contact time (Figure 3-6). Faster-moving water requires the use of special herbicide formulations such as slow-release pellets. Rapidly absorbed herbicides are also more effective for controlling weeds in fast-moving water if these materials are available for the weed species you are trying to control.

Water Characteristics. Factors such as water pH, turbidity, and hardness often influence how well an aquatic herbicide works. The pH of the water affects the rate at which plants absorb herbicides and may also affect the breakdown rate of the active ingredient. Particles suspended in the water—including plankton, organic materials, or minerals—adsorb or bind the

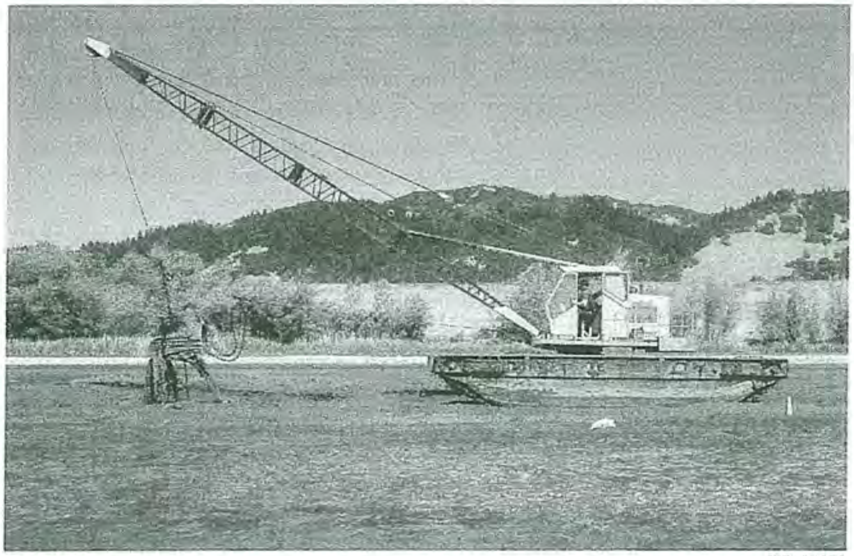

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FIGURE 3-7.

Large equipment used for managing aquatic weeds can be very dangerous. Workers operating this equipment must be trained in safety procedures and proper methods of operation.

molecules of certain herbicides and prevent them from reaching the target plants.

Dissolved salts and minerals affect the hardness of the water. Certain herbicides, such as glyphosate, lose some of their effectiveness when mixed with hard water. Some herbicides precipitate (come out of solution) when mixed with hard water, while others are changed chemically. As an example, when copper sulfate is used in hard water having a pH of 8 or above, copper carbonates form, and these carbonates are ineffective in controlling the target weeds.

MECHANICAL CONTROL

Mechanical control involves cutting or removing weeds by hand or by machine. This was the most common method used to manage aquatic weeds until the widespread use of herbicides began in the 1950s.

Mechanical control methods require no pesticide permits or knowledge of pesticide laws and regulations. And unlike most pesticide applications, manual and machine removal methods can be performed regardless of wind or other weather conditions. The harvested vegetation has potential for use as mulch, fertilizer, feed for livestock, or in methane gas production. Rapid control is achieved and, unlike in herbicide-treated waters, leftover dead and dying vegetation is minimized. In most cases, water from the areas where mechanical removal takes place can be used immediately for drinking and irrigation.

Both manual and machine removal methods have certain disadvantages. Manual methods are time-consuming, labor-intensive, and must be repeated frequently. Machine removal can also be costly and introduces additional hazards (Figure 3-7), requiring that workers have training in safety procedures and operation of heavy equipment.

Manual Removal. Manual methods of control include hand pulling or

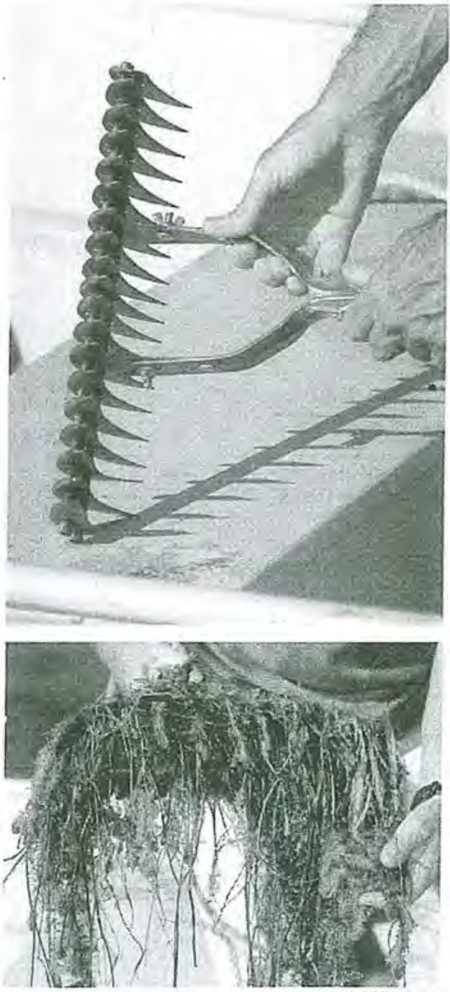

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FIGURE 3-8.

Common "thatch" rakes make excellent tools for detecting and removing aquatic weeds. They can be attached to a pole or to a line. The rake at the bottom is filled with aquatic weeds.

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FIGURE 3-9.

Draglining is frequently used to remove vegetation and sediments from irrigation and drainage ditches.

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FIGURE 3-10.

Special weed cutters are used in large areas to slash underwater rooted vegetation. This machine is cutting hydrilla.

using hoes, rakes (Figure 3-8), shovels, scythes, and other hand-held tools. Sometimes special weed cutters are used to cut and remove aquatic weeds—a person throws the cutter, attached to a rope, into the weedy area and pulls in the vegetation.

Machine Removal. Controlling weeds by machine includes draglining, cutting and mowing, dredging, and weed harvesting.

Draglining involves dragging a heavily weighted device along the bottom sediment to dislodge the weeds. This method is frequently used to remove vegetation and sediments from irrigation and drainage ditches (Figure 3-9).

Cutting and mowing aquatic weeds involves using underwater or shoreline mowers. Like mowing a lawn, this method must be repeated at regular intervals. Special weed cutters are used primarily in large lakes or rivers to slash underwater rooted vegetation, usually 4 to 6 feet below the water's surface (Figure 3-10). Some weed cutting boats are equipped with sharp blades that can shred small trees and cattails, easily clearing boat paths. Another machine, the hydraulically operated *rotovator*, works like an underwater rototiller and is used in some situations to tear up roots, rhizomes, and tubers from bottom sediments.

FIGURE 3-11.

This dredger is scooping hydrilla from a canal. Dredging deepens a channel as well as removing weed growth.

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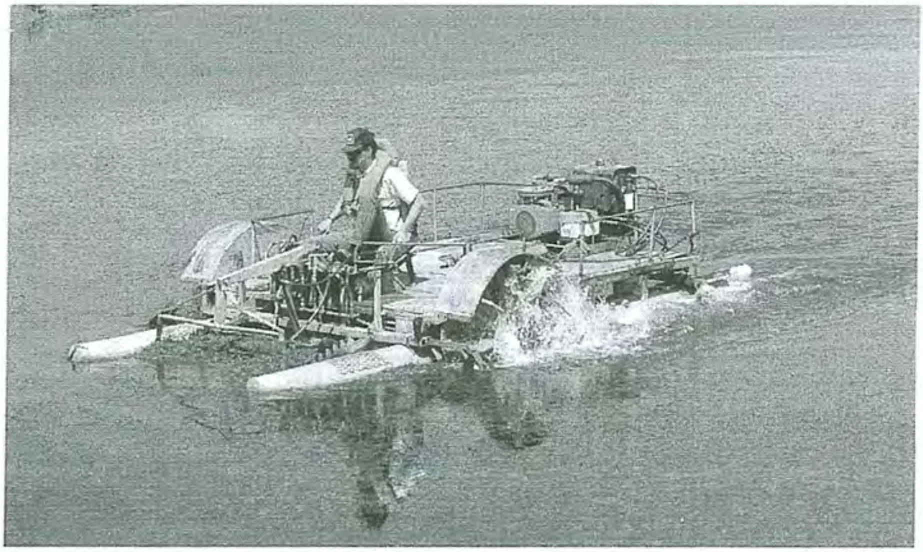
FIGURE 3-12.

A weed harvester (right) reduces the spread of cut fragments and eliminates foul-smelling, unsightly messes caused by decomposing weeds. Trucks haul away cut and harvested weeds (below).



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Dredging deepens a body of water by digging or scooping up sediment (Figure 3-11). Some dredgers are amphibious and consist of specially adapted barge-mounted excavators fitted with legs. They are particularly good for use along shorelines and in other areas that conventional equipment cannot reach.

Weed harvesting means not only cut ing the weeds but also removing the cut vegetation from the water to prevent massive amounts of decomposing weeds from depleting oxygen and causing fish kills. Harvesting reduces the spread of cut fragments and eliminates foul-smelling, unsightly messes caused by decomposing weeds (Figure 3-12). Mechanical harvesters are usually unsuitable for removing vegetation in water less than 3 feet deep and may also be unsuitable to use where there are large rocks or other obstructions in the water.

The disruption caused by mechanized equipment can temporarily increase water turbidity. The cutting process is usually nonselective, so both nuisance and desired vegetation will be removed. The process may also destroy wildlife such as small fish, snakes, and turtles. Mechanical control methods increase infestations of weeds that reproduce mainly by fragmentation and stolons, such as Eurasian watermilfoil, egeria, and hydrilla. The process can also dislodge hydrilla tubers and spread these long-lived structures. Repeated harvesting tends to lower the nutrient content of a lake or pond, since nutrients are removed with the harvested plants.

Dredging and dumping permits may be required (Figure 3-13), and other permits may be needed to transport equipment on public roads and to launch it from waterfronts.

CULTURAL CONTROL

Cultural control involves altering the environment to inhibit the growth of aquatic plants. This may be an effective control method for small ponds in recreational or residential areas. However, the cultural methods described below may not be suitable for larger bodies of water, protected areas, or rivers and streams.

Design. Taking advantage of design elements that discourage weeds can

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FIGURE 3-13.

Harvested weeds must be dumped far enough away from the water to prevent fragments or seeds from washing back into the water and regrowing.

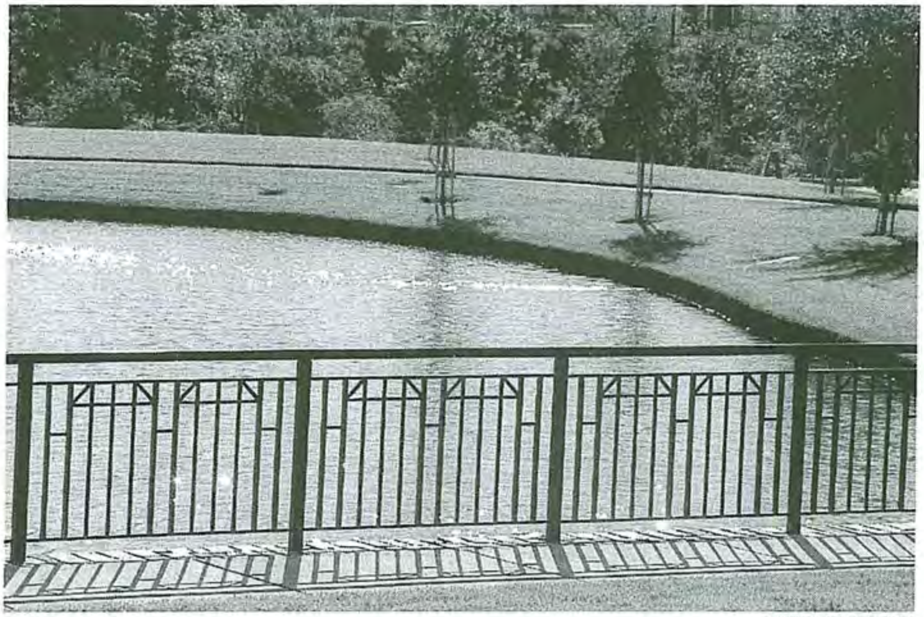
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FIGURE 3-14.

Proper lake design can discourage the growth of aquatic weeds. However, steep slopes and deep edges can create hazards to animals and small children.


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FIGURE 3-15.

Nutrient control of a body of water is difficult when birds fertilize the water with their feces.

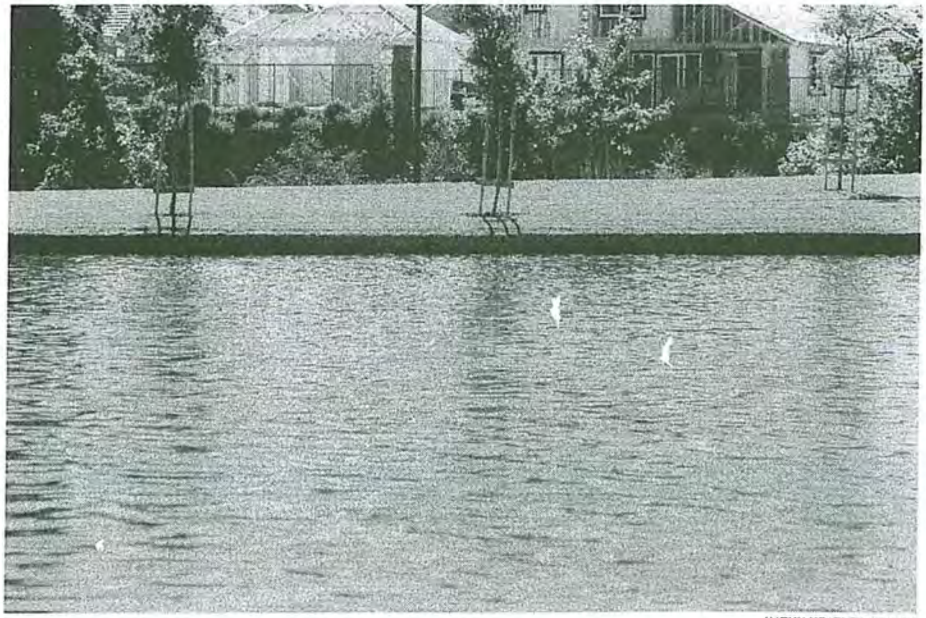
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FIGURE 3-16.

Planting sod along a lake or pond can help prevent fertilizer runoff from fields and ornamental plantings. However, it is important to include a raised area to separate the grass from the water to prevent runoff.

prevent excessive aquatic growth (Figure 3-14). Because weeds grow best in areas that are less than 3 feet deep, creating ponds and lakes with steep slopes and sharp drop-offs eliminates the shallow areas where weeds flourish. However, sharp drop-offs and steep slopes create hazards to children and some small animals.

Other design methods include pouring concrete bottoms and sides, lining the shore with rocks or other *riprap* to prevent erosion and weed establishment, and lining pond bottoms with black plastic to prevent weeds from taking root.

Nutrient Control. One way to reduce aquatic weed growth is to limit their essential nutrients. However, reducing nutrients may decrease one weed species and promote the growth of others. For example, nutrient limitation will control planktonic algae populations, but the increased light penetration to the sediment may result in more rooted weeds or more vigorous growth of these weeds. Nutrient control may be difficult if you cannot prevent animals and birds (Figure 3-15) from fertilizing the body of water, or if the site is located near septic tanks or fertilized land.

The presence of excessive nutrients caused by fertilizer runoff from fields and ornamental plantings stimulates rapid and excessive aquatic weed growth. Ways you can alleviate this problem include

- planting grass sod along a lake or a pond shoreline with a *berm* separating the grass from the water to prevent fertilizer runoff (Figure 3-16)
- avoiding fertilizing any grass that grows within 10 to 20 feet of the shoreline to keep nutrients from reaching the water
- keeping livestock and other animals away from the shoreline to prevent sedimentation, nutrient enrichment, and soil erosion
- preventing runoff from nearby septic tanks and leach fields
- constructing settling or retention ponds to stop or partially block runoff containing nutrients from reaching the body of water

Water-Level Manipulation. Water-level manipulation involves raising or lowering water levels to control aquatic weeds (Figure 3-17). This manipulation results in destroying plants either by drowning the emergent weeds or by exposing the submersed weeds to freezing, drying, or heat. Drawdowns kill the underground root systems of many weeds. A drawdown, however, can give many emersed weeds a competitive advantage. Table 3-2 shows

TABLE 3-2.

Impact of Water Drawdowns on Aquatic Weed Growth.

Water drawdowns control many plants effectively. Some plants, however, can tolerate the lower water levels, and for still others, drawdowns can be advantageous. The timing of the drawdown determines which plants are affected.
Growth controlled by drawdowns
egeria (*Egeria densa*)
largeleaf pondweed (*Potamogeton amplifolius*)
purple fanwort (*Cabomba caroliniana*)
waterlily (*Nymphaea tuberosa*)
watershield (*Brasenia schreberi*)
Growth moderately controlled by drawdowns
leafy pondweed (*Potamogeton foliosus*)
Richardson's pondweed (*Potamogeton richardsonii*)
smartweed (*Polygonum natans*)
Growth not influenced by drawdowns
cattail (*Typha latifolia*)
coontail (*Ceratophyllum demersum*)
sago pondweed (*Potamogeton pectinatus*)
soft stem bulrush (*Scirpus validus*)
waterprimrose (*Ludwigia* spp.)
Growth enhanced by drawdowns
curlyleaf pondweed (*Potamogeton crispus*)
naiads (*Najas* spp.)
watermilfoils (*Myriophyllum* spp.)


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FIGURE 3-17.

This pumping unit is lowering the water level in a small lake. Raising or lowering water levels can help control aquatic vegetation.

the impact of drawdowns on different aquatic weed species.

Drawdowns are usually low-cost and practical control methods unless recreational use or the power generation potential of the body of water is lost. Secondary benefits of a drawdown might include inproving the quality of fish populations. For example, in some lakes a partial drawdown concentrates fish into a small, deep area away from the shoreline and shallow weed zone. This allows the larger game fish to prey more heavily on nongame or less desirable fish.

Drawdowns also have some disadvantages. For instance, lowering water levels may force wildlife to move to new, less desirable locations. There is the risk that weeds will invade deeper areas of the pond or lake. Also, drawdowns can increase problems with certain types of mosquitoes. In addition, drawdowns may create complicated problems involving water rights and water-use patterns.

Nontoxic Dyes. Because aquatic weeds and other aquatic plants require sunlight, reducing the amount of light passing through the water can control the growth of these plants. Nontoxic dyes applied to the water act as light screens. Dyes are generally effective on rooted, submersed weeds growing at depths greater than 2 to 4 feet. They work only in bodies of water with little or no outflow, because flowing water quickly dilutes the dye concentration. Dyes are not recommended for muddy waters, since suspended particles already screen the light.

Dyes are not toxic to aquatic organisms, people, or animals that might drink the treated water. However, these dyes are registered as pesticides and therefore must be applied strictly according to label directions. Since many aquatic weeds can produce very long shoots, it is essential to apply dyes in the spring, before shoots can reach the surface. Once weeds have access to sunlight at the water's surface the dyes have little effect.

Bottom Barriers. Black plastic and specially manufactured bottom covers or weed barriers are used in small ponds and near boat docks and swimming beaches to keep rooted aquatic weeds from growing. The barriers are held in place by stakes or are weighted with sand or gravel. They prevent light from reaching the bottom where weeds would normally root. Gases produced on pond bottoms sometimes accumulate under plastic barriers and cause them to float to the surface; using barriers made from gas-permeable materials solves this problem. Barriers are costly to purchase and install, and sediment that collects on top of them must be removed periodically to prevent plants from taking root there.

Aeration. Aeration, or oxygenation, improves water quality and reduces some aquatic weed problems. Aeration is used to help control the buildup of algae, bottom sludge, and odors in ponds and small lakes (Figure 3-18). It helps reduce phytoplanktonic algae production, shifting blue-green algae dominance to other more desirable green-algae species. However, aeration cannot be expected to control filamentous algae and rooted weeds.

Aeration may prevent fish deaths by maintaining suitable oxygen concentrations during the summer or winter. In addition, water circulation, coupled with predators like mosquitofish, helps reduce mosquito populations. Two types of aeration are used: injecting air into deep anaerobic (oxygen depleted) water, and pumping bottom water to the surface, where it is mixed with air and reintroduced to the bottom.

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FIGURE 3-18.

Aeration of the water in ponds or small lakes helps to reduce phytoplanktonic algae production.

BIOLOGICAL CONTROL

Biological control uses parasites, predators, competitors, herbivores, or disease-causing agents to reduce or suppress aquatic pests. Classical biological control involves introducing natural enemies from the part of the world where the pest plant originated. Importing and introducing natural enemies requires special permits and involves lengthy host-specific testing and quarantine periods to ensure that the imported organisms will not become pests.

Biological control of aquatic weeds is currently not widespread in California, nor is it universally successful. The concept, however, has the potential for providing long-term control of certain aquatic weed pests, similar to the successes that have helped to control some exotic terrestrial weeds.

Parasites include disease-causing fungi that infect specific plants. An example is *Cercospora rodmanni*, which is used to control waterhyacinth. *Predators* include organisms such as the alligatorweed beetle (used to control alligatorweed) and grass carp (used to remove aquatic vegetation from irrigation canals, farm ponds, and golf course ponds). A root-boring weevil and two leaf-feeding weevils (Figure 3-19) are being used in parts of California to control large stands of purple loosestrife (see Sidebar 9). *Competitors* include rooted floating plants that shade submersed weeds. *Pathogens* may include viruses that attack certain plants.

Herbivorous Fish. The use of herbivorous fish for aquatic weed control in California is very limited and highly regulated. State laws ban the use of nonsterile (diploid) grass carp, but do allow certain strict and limited uses of sterile (triploid) grass carp with

SIDEBAR 9

Biological Control of Purple Loosestrife

Some insects are used to control exotic weed species. However, before insects are imported from the plant's native range, extensive feeding studies are conducted to make sure the insects are sufficiently host specific and will not damage agricultural crops.

For example, from 1993 to 1998, the United States approved five insects to feed on purple loosestrife. They included two leaf-feeding beetles, a root-feeding weevil, and two seed-feeding weevils. None feeds on any crop species.

The leaf-feeding beetles include *Galerucella calmariensis* and *G. pusilla*, native to Europe and Asia. Both species lay eggs only on purple loosestrife and feed only on that plant.

For specific information on biological control of purple loosestrife, visit the Purple Loosestrife InfoCentre on the Ducks Unlimited Canada website, *http://www.ducks.ca/purple/biocontrol/index.html*, developed and maintained by the Manitoba Purple Loosestrife Project. Another comprehensive site is: *http://www.dnr.cornell.edu/bcontrol/*, developed by Cornell University Department of Natural Resources. Ducks Unlimited (U.S.) maintains a similar site at: *http://www.ducks.org*.

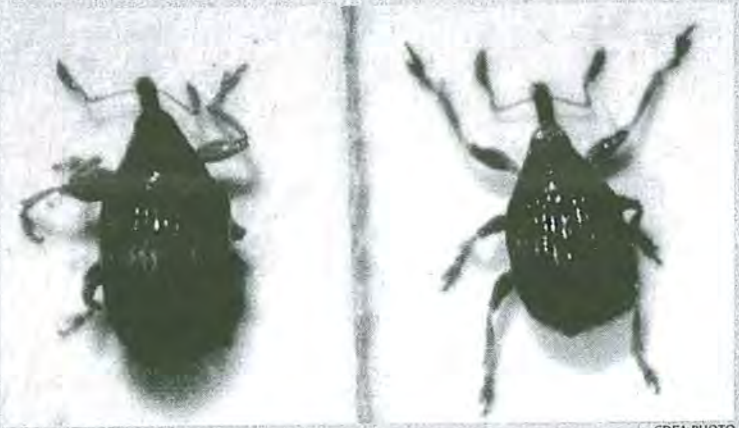

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FIGURE 3-19.

This flower-feeding weevil, Nanophyes marmoratus, *is a natural enemy of purple loosestrife. It attacks the flowers and seed capsules.*

IMPERIAL COUNTY IRRIGATION DISTRICT

FIGURE 3-20.

Sterile (triploid) grass carp are used in certain parts of California to control hydrilla infestations in irrigation canals.

FIGURE 3-21. CDFA PHOTO

Insects, such as this weevil Bagous affinis, *are being tested for their potential to control hydrilla. In this photo, the adult weevils are feeding on a hydrilla tuber.*

appropriate authorization by the California Department of Fish and Game (Figure 3-20). Permits are required to ensure that the fish are sterile and will not escape to areas where they are not wanted. For instance, in some areas they are limited specifically to golf course ponds, livestock watering ponds, and other bodies of water that have no outlets and are not in any 100-year flood plains. These species cannot be introduced into natural bodies of water such as lakes, rivers, and wetlands, because they would destroy vegetation required by other organisms.

Insects. The first aquatic weed targeted for biological control in the United States was alligatorweed. Three host-specific insects from South America feed on this weed: the alligatorweed flea beetle, the alligatorweed thrips, and the alligatorweed stem borer. Also, three species of insects are being used to help control waterhyacinth: the mottled waterhyacinth weevil, the chevroned waterhyacinth weevil, and a moth known as the waterhyacinth borer. Researchers are currently testing insect biological controls for waterlettuce, hydrilla (Figure 3-21), and Eurasian watermilfoil.

Fowl. Swans, geese, and ducks (Figure 3-22) have been used with some success to control submersed weeds. However, their waste products increase the fertility of the water, which can promote phytoplankton blooms. In addition, some waterfowl serve as hosts for the organism that causes "swimmer's itch."

INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) is an ecological approach to managing pests. IPM is geared toward providing economical long-term protection from pest damage or competition. Factors such as prior pest history, influences of weather, visual observations, pest monitoring information, existing cultural practices, uses of the aquatic site, budget, efficacy, public perceptions and concerns, and laws become a part of the pest management decision process.

IPM programs depend on careful monitoring to anticipate weed problems, and they involve the use of methods that will prevent weed growth and competition for nutrients, space, and light. Goals include protecting

FIGURE 3-22. KATHY KEATLEY GARVEY

Swans, geese, and ducks are being used with some success to control submersed weeds in ornamental ponds.

native plants and animals, conserving natural enemies, and avoiding secondary pest problems. IPM programs use a combination of chemical, mechanical, cultural, and biological control methods. Chemical control methods are integrated with other options when decision-making guidelines and field-collected data indicate that their use is economically and environmentally justified.

Concern about pesticides in the environment and their potential harm to users and the public has increased in recent years. IPM addresses many of the problems associated with chemical pest control by relying on careful and continual pest monitoring and consideration of all alternatives. Sometimes pesticide applications can be avoided completely, or, when they are needed, they can be timed more accurately. With IPM, pesticide applications are reduced to the minimum possible level that still offers effective control. This is not only economically beneficial but generally poses a lower risk to people and the environment.

Ongoing programs in many non-aquatic locations confirm that long-term control of certain pests has been achieved through IPM and that this reduces reliance on more expensive, short-term pest treatments, including some pesticides.

Establishing an IPM Program

Establishing an IPM program involves gathering information, making decisions, implementing those decisions, and evaluating the results. Continual site monitoring, evaluation, and adjustments to the control program are crucial. Information needed for making IPM-based decisions includes: correct pest identification; site characteristics; site uses and the site's economic, aesthetic, or recreational significance; which management methods have the least impact on people and the environment; and results from monitoring and evaluating previous management efforts. Sidebar 10 lists some of the important information that can help you develop an effective management strategy for pests in an aquatic area.

Identify the Pest. Correct pest identification is necessary for several reasons. First, you need to know if the suspected pest has the potential to damage the aquatic system. For example, Eurasian watermilfoil (*Myriophyllum spicatum*), a troublesome pest, resembles another watermilfoil species, Northern watermilfoil (*M. sibericum*), that is not considered a pest species. Proper distinction between these two species

CDFA PHOTO

FIGURE 3-23.

Site evaluation and gathering and collecting information is an important step in planning a control strategy. These scuba divers are collecting submersed weeds so they can be identified before control efforts are begun.

SIDEBAR 10

Information Helps You Develop Aquatic Weed Management Strategies

The goal of integrated pest management (IPM) programs in aquatic settings is to reduce pests to an acceptable level with the least amount of disruption to other organisms in the surrounding environment. Completely eradicating the aquatic weeds is usually impossible, but you should be able to effectively reduce them to an acceptable level and maintain that level. You can accomplish this by using an array of management tools and tactics. To plan a management strategy, you need some specific information. Begin by considering the following:

USES OF THE BODY OF WATER

- ☐ What are its current and future uses?
- ☐ What is the ultimate use or fate of the water once it leaves the site?
- ☐ What are the attitudes and expectations of the site users and managers regarding weed control efforts and methods?

PHYSICAL ATTRIBUTES OF THE SITE

- ☐ Is the body of water flowing or static?
- ☐ What is the size of the area?
- ☐ What are the average and maximum depths of the body of water?
- ☐ What type of slope does the shoreline have?
- ☐ What are the characteristics of the bottom sediment?
- ☐ What is the pH, clarity, temperature, and hardness of the water?

THE WEED PESTS

- ☐ Which aquatic weeds are present?
- ☐ Why are these weeds considered pests at this site?
- ☐ Where do they occur within the site?
- ☐ Have there been previous control efforts targeting these weed pests? If so, what were the results?

LOCATION OF THE AQUATIC SITE

- ☐ Is the site located near to or adjoining sensitive areas such as agricultural land, residences, recreational facilities, or industrial complexes?
- ☐ Are there special structures or facilities such as wells, sewer lines or sewage treatment plants, septic systems, or livestock operations that may impact the aquatic site?
- ☐ What are the prevailing weather conditions at this site at various times of year?

ENVIRONMENTAL CONSIDERATIONS

- ☐ What nonpest plants and animals are found in the area?
- ☐ Are there any endangered or threatened species in the area?
- ☐ Are there natural enemies present that might contribute to controlling the target pests?
- ☐ Do any specific air and water quality regulations apply to this site?
- ☐ Are there sources of nutrients such as in runoff water from turf, landscape, and other ornamental areas?

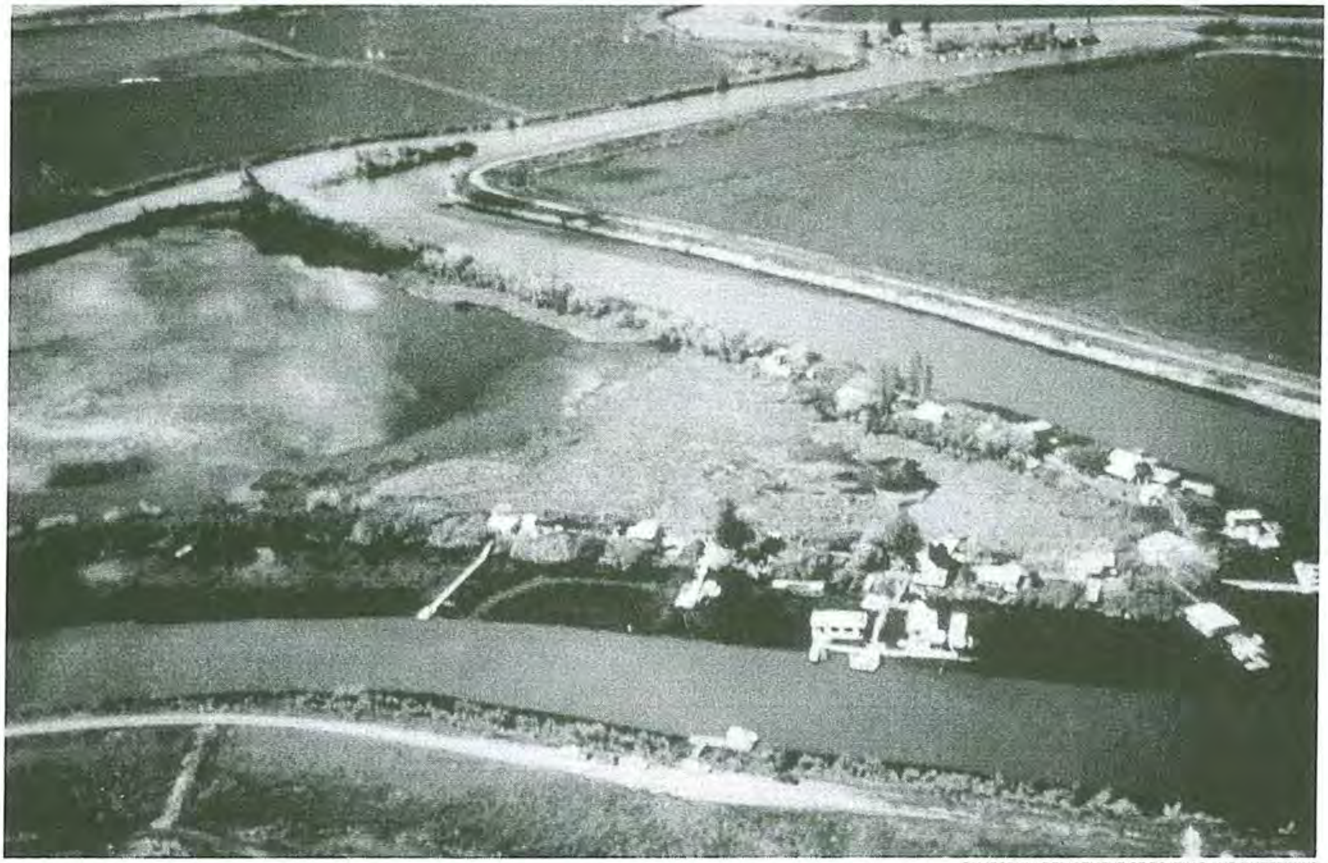


FIGURE 3-24. CALIFORNIA DEPARTMENT OF BOATING AND WATERWAYS

Using aerial photographs of a waterway assists in determining the extent of a weed infestation and helps in predicting the potential for the spread of the weeds. This photo shows an egeria infestation.

is needed to avoid unnecessary control efforts.

After identifying a potential pest, you can learn about its life cycle and determine which life stage is most vulnerable to control efforts. For example, applying an herbicide to pondweed in the late summer hinders the weed from accumulating the necessary nutrients for its food-storing tubers. This reduces the weed's ability to overwinter.

Identifying the pest also gives you access to information that helps you decide which control methods should be used. Chemical, mechanical, cultural, and biological controls may each have distinct advantages and limitations for particular aquatic species.

Evaluate the Site. Aquatic site evaluation involves making observations and gathering and recording information that may influence your choice of control methods or the ways you use these methods (Figure 3-23). Key factors include physical features of the site such as size and depth of the body of water, location of rocks and other obstructions, prevailing wind and other pertinent weather conditions, and the nature of the surrounding area. You must also determine which pest populations are present, their life stages, and their distribution within the area (Figure 3-24). In addition, you need information about the water characteristics, such as clarity, hardness, temperature, flow, and other factors that may influence control efforts.

Understand the Present and Future Uses of the Site. When considering control options, you must be aware of present and future uses of the aquatic site and where water may flow to from that site. Determining the uses of a body of water allows you to set priorities that influence your pest management decisions. The uses of the site almost always affect what types of aquatic herbicides can or cannot be applied. For example, because of the restrictions on the use of certain herbicides around meat or dairy animals, herbicides selected to control a blue-green algae infestation in a livestock watering pond could be different from those used to control a blue-green algae infestation of navigational waters.

FIGURE 3-25.

Providing information about weed pests to people who live near a waterfront may help prevent serious infestations. This sign warns against putting hydrilla plants from aquariums into the lake.

CDFA PHOTO

There are also aesthetic and recreational factors to consider. For instance, homeowners living near a waterfront may have certain ideas about which vegetation should be controlled and how, but their notions may be in conflict with the local aquatic weed control agency plans. In fact, plants a homeowner finds attractive may be serious pests. In addition, homeowners may prefer weed infestations to the disruption of control efforts, or they may be intolerant of all plants and algae, preferring instead crystal clear water.

Select Management Methods. Based on the results of the site assessment, select effective methods that cause the least disruption to the environment and pose the least risk to people. Consider the cost of each control method and determine the potential benefits each will contribute. If the management program involves using pesticides, become familiar with the limitations, restrictions, and laws and regulations dealing with pesticide applications. Consider their impact on people, endangered species, wildlife, and water and air quality. In addition, find out what the public's perceptions and concerns are regarding using pesticides and other control methods so you can address these. Recruit the help of people who live nearby or who use an aquatic area by making them aware of how certain plants cause problems and showing them steps they can take to help prevent the establishment of some aquatic weeds (Figure 3-25).

Evaluate the Control Efforts. All successful IPM programs have an evaluation component to measure the success of management methods. The evaluation will also help you spot secondary pest outbreaks or other problems created by controlling target pests.

REVIEW QUESTIONS

(answers on page 145)

1. **Which one of the following four main management methods for aquatic weeds is the most commonly used?**
   - ☐ a. Chemical control
   - ☐ b. Mechanical control
   - ☐ c. Cultural control
   - ☐ d. Biological control

2. **Which of the following is true?**
   - ☐ a. When properly applied, most herbicides control aquatic vegetation without harming fish and other wildlife
   - ☐ b. Even when properly applied, most herbicides do not control aquatic vegetation without harming fish and other wildlife
   - ☐ c. When properly applied, most herbicides control aquatic vegetation, but they cause considerable harm to fish
   - ☐ d. All aquatic herbicides, no matter how applied, adversely affect people and the environment

3. **When planning to use herbicides in your aquatic weed control program, the first thing you should do is:**
   - ☐ a. Define the goals of the control efforts
   - ☐ b. Know the current and future use or uses of the water to be treated
   - ☐ c. Identify the weeds
   - ☐ d. Understand the water characteristics, including temperature, alkalinity, and water flow

4. **Adjuvants are:**
   - ☐ a. Materials added by the applicator to the spray tank to improve the herbicide action or its ability to be applied
   - ☐ b. Active ingredients in a pesticide mixture
   - ☐ c. Materials that are sprayed onto target areas after the herbicide is applied
   - ☐ d. Materials added to the spray tank to lubricate the pump and reduce corrosion of metal parts

5. **Which of the following is true?**
   - ☐ a. Because of their uniform shape and size, granules tend to deliver more uniform coverage and allow for more accurate calibration than pellets
   - ☐ b. Because of their uniform shape and size, pellets tend to deliver more uniform coverage and allow for more accurate calibration than granules
   - ☐ c. Pellets and granules are the most effective formulations for applying contact herbicides to leaf surfaces
   - ☐ d. Pellets present more operator hazards than liquid formulations

6. **Contact herbicides:**
   - ☐ a. Destroy the plant tissues they directly contact
   - ☐ b. Kill only the shallow roots
   - ☐ c. Move through the plant to the roots, where they disrupt normal plant functions
   - ☐ d. Are taken up by the plant roots and move to the leaves

7. **Systemic herbicides:**
   - ☐ a. Destroy the plant tissues they directly contact
   - ☐ b. Kill only the plant leaves
   - ☐ c. Move through the plant to such sites as the roots, where they disrupt normal plant functions
   - ☐ d. Cannot be used for controlling aquatic weeds

8. **Selectivity refers to:**
   - ☐ a. The ability of an herbicide to control specific weeds
   - ☐ b. The ability of an herbicide to control a broad range of emergent vegetation
   - ☐ c. The time of year of herbicide application
   - ☐ d. How an herbicide moves internally through the plant

9. **Which one of the following statements is *not* true?**
   - ☐ a. Some systemic soil-applied herbicides are most effective on annuals in the early stages of growth
   - ☐ b. Foliar-applied systemic herbicides are most effective on perennials during the late and postflowering stages when the plants are completing their growth rate
   - ☐ c. Fall treatments of many aquatic weeds have proven very successful, often requiring a lower herbicide rate because of the higher plant translocation activity
   - ☐ d. The growth stage of the treated plants does not affect selectivity

10. **Which of the following statements is true?**
    - ☐ a. Environmental factors, including weather conditions, water movement, and soil and water chemistry, affect how well aquatic herbicides work
    - ☐ b. Water movement usually has little effect on how well aquatic herbicides work

☐ c. Water chemistry has no influence on aquatic herbicides

☐ d. Soil chemistry has no influence on aquatic herbicides

11. Manual methods of aquatic weed control do *not* include using:

☐ a. Hoes

☐ b. Rakes

☐ c. Scythes

☐ d. Powered mechanical mowers

12. Aquatic weed harvesting involves:

☐ a. Disturbing the weed roots

☐ b. Mowing the weeds

☐ c. Draglining the weeds

☐ d. Cutting the weeds and removing the cut vegetation from the water

13. Which of the following is *not* true?

☐ a. Mechanical harvesting is an effective way to eliminate all aquatic weeds

☐ b. Mechanical harvesting will increase populations of such weeds as Eurasian watermilfoil, ergeria, and hydrilla, which reproduce mainly by fragmentation and stolons

☐ c. Repeated mechanical harvesting may lower the nutrient content of a body of water

☐ d. Mechanical harvesting of hydrilla can dislodge tubers and spread them

14. Which of the following is *not* a cultural control method?

☐ a. Designing a lake with steep sloping banks

☐ b. Keeping livestock away from a pond

☐ c. Preventing runoff from nearby septic tanks and septic fields

☐ d. Using a boat-mounted weed cutter

15. Which of the following is *not* an advantage of using water drawdowns to control aquatic weeds?

☐ a. Drawdowns kill the underground root systems of many aquatic plants

☐ b. Drawdowns help control submersed and rooted floating weeds and alter fish populations

☐ c. Drawdowns give many emersed weeds a competitive advantage

☐ d. Drawdowns allow the control of certain weeds without the use of herbicides

16. Which of the following is *not* true about using nontoxic dyes to control aquatic weeds?

☐ a. Nontoxic dyes act as light screens that can inhibit plant growth

☐ b. Rapidly flowing water will quickly reduce the dye concentration and render the dye ineffective

☐ c. Dyes generally work best on emersed weeds

☐ d. Dyes work best on submersed plants

17. Bottom covers, usually of black plastic, are a method of:

☐ a. Chemical control

☐ b. Cultural control

☐ c. Biological control

☐ d. Mechanical control

18. Which of the following is *not* an example of biological control?

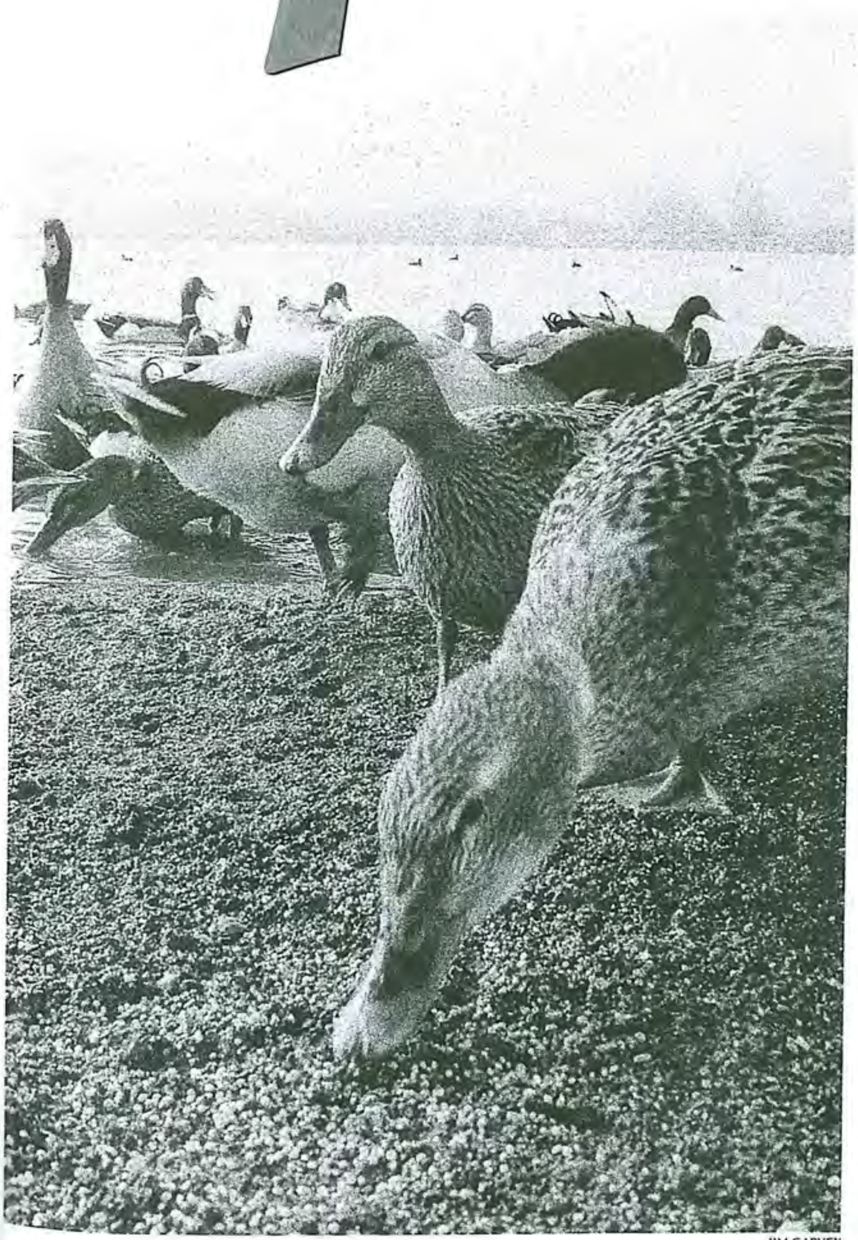
☐ a. Using mosquitofish to control mosquito larvae

☐ b. Using grass carp to control hydrilla

☐ c. Using the disease-causing fungus *Cercospora rodmanni* to control waterhyacinth

☐ d. Using a nontoxic dye to control coontail

4 Other Pests in the Aquatic Environment



JIM GARVEY

Waterfowl can be nuisances in parks and around ponds and small lakes.

Besides aquatic weeds, you may also need to control animals that become pests in aquatic areas. These include some *invertebrates* such as insects, crabs, and mussels and a few *vertebrates*—certain fish, birds, and mammals. As pests, these invertebrate and vertebrate organisms compete with or destroy native plants and animals, interfere with water flow, weaken levees and embankments, or cause health hazards to people or livestock.

INVERTEBRATE PESTS

Invertebrates are usually considered aquatic pests if they

- create health or safety hazards
- impede water flow and hinder navigation
- clog hydraulic systems such as pipes and water intakes
- interfere with human activities
- are annoying or nuisances

For example, some species of mosquitoes transmit organisms that cause malaria, encephalitis, other human diseases, and canine heartworm. Pest clams and crabs interfere with water transmission systems in California. Certain snails harbor parasitic larvae that burrow into human skin. And mammals such as squirrels and rats damage levees and other structures with their burrowing activities.

Insects

The insects that are of most concern in aquatic environments are mosquitoes, black flies, and midges that feed on the blood of people or other animals. Some of these are capable of transmitting disease organisms during blood feeding. Other insects become nuisances when they occur in recreational areas in large numbers or occasionally inflict painful bites on swimmers. The larval stages of some aquatic insects attach to pipes or other structures in sufficient numbers that they reduce water flow.

Mosquitoes

Mosquitoes (Figure 4-1) are the most serious aquatic insect pests, because some species vector human and animal disease organisms (see Sidebar 11). The most significant pest genera are *Anopheles*, *Culex*, and *Aedes*. *Anopheles* species are the principal malaria-carrying mosquitoes.

Mosquitoes belong to the order Diptera, which also includes flies, midges, and gnats. Adults in this order have sucking mouthparts and only one pair of wings. Mosquitoes are distinguished from other Diptera by the structure of their mouthparts, which include a slender proboscis. Adult females use this specially adapted proboscis to penetrate skin and feed on blood. Experts identify mosquito species by the scales along the wing veins and body. Scales of individual species vary in color and arrangement.

Of the more than 2,600 species of mosquitoes worldwide, approximately 50 live in California. Only adult females feed on blood, but not all females are blood-feeders. Adult male mosquitoes generally feed on nectar

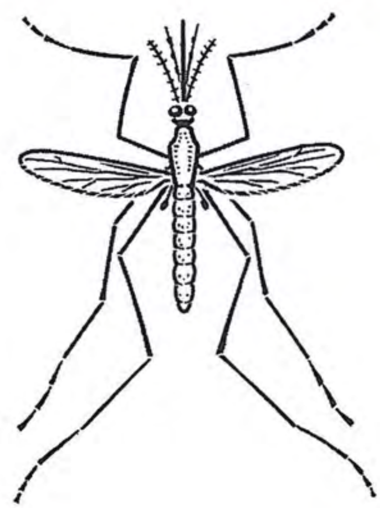
SIDEBAR 11

Diseases Transmitted by Mosquitoes

Adult female mosquitoes are blood-feeding pests of people and animals. Mosquito bites usually result in red, swollen areas that itch severely and may persist for several days. Some species of mosquitoes also vector microorganisms to people or animals. These microorganisms include those that cause malaria, yellow fever, encephalitis, dengue, canine heartworm, and filariasis.

MALARIA

Malaria is a serious disease caused by protozoan parasites passed on in the saliva of an infective mosquito each time it takes a new blood meal. The parasites penetrate red blood cells, multiply, and progressively break down the cells. This induces bouts of severe fever and anemia. Left untreated, malaria can cause kidney failure, coma, and death. The occurrence of malaria in California, however, is extremely low.



DAVID KIDD

FIGURE 4-1

Mosquitoes belong to the insect order Diptera. They are the most serious aquatic insect pests because of their potential to vector disease organisms.

ENCEPHALITIS

Several species of mosquitoes transmit encephalitis viruses to people and animals. In the majority of human cases, these viral infections manifest themselves only as general flu-like symptoms, ending with full recovery. Infection may, however, lead to encephalitis (inflammation of the brain), which can be fatal or leave permanent neurological damage. *Culex* spp. mosquitoes transmit the virus that causes St. Louis encephalitis and Western equine encephalitis. Severe cases of St. Louis encephalitis can cause seizures, double vision, paralysis, and death. *Aedes* spp. mosquitoes transmit the viruses that cause LaCrosse and Eastern equine encephalitis.

CANINE HEARTWORM

Canine heartworm infects dogs and related canines (foxes, coyotes, and wolves) and cats through mosquito feeding activities. Tiny microfilarial worms, a lifestage of the filarial nematode *Dirofilaria immitis,* enter the animal's blood through the mosquito bite. Once inside the animal, they grow quite large, measuring up to 10 inches long, and they typically live in the animal's pulmonary artery and "right" heart. The resulting thickening and inflammation of the heart cause symptoms such as difficulty breathing, chronic cough, and vomiting, and the disease can be fatal. Canine heartworm occurs worldwide and is transmitted by several species of mosquitoes.

and other plant juices.

Mosquitoes typically breed and lay their eggs in water clogged with such vegetation as waterlettuce, hydrilla, waterhyacinth, and cattail. They also deposit their eggs in drainage ditches, on river and stream flood plains, and in other standing water.

Mosquito-Transmitted Disease Organisms. Mosquitoes in the United States transmit several blood-borne disease organisms. In California, mosquitoes vector the organisms that cause two important human diseases, malaria and encephalitis. In addition, mosquitoes vector the canine heartworm organism, a parasite that causes a serious and often fatal illness in dogs and cats.

Controlling Mosquitoes. The most effective mosquito control method involves draining or eliminating breeding areas. When this is not possible, control efforts include spraying insecticides and using natural enemies such as small larvae-eating fish.

Mosquito abatement districts in California are responsible for controlling mosquito breeding areas. *Before beginning any mosquito management efforts, contact your local mosquito abatement district for information and coordination of efforts.*

Draining. The task of draining or eliminating breeding areas includes cleaning drainage ditches of debris and weeds (Figure 4-2), packing tree holes with sand or cement, emptying or overturning water-holding containers, and covering structures and vessels that could hold water and serve as mosquito-breeding areas.

Biological Control. Mosquitofish are effective biological control agents for mosquito larvae (Figure 4-3). The term "mosquitofish" usually refers to *Gambusia affinis*, a species that resembles guppies. Used in mosquito control in California since 1921, the mosquitofish is an extremely important biological control agent. Mosquito abatement districts stock them in marshlands, canals, roadside ditches, creeks, ponds, garden pools, rice fields, livestock-watering ponds, and water-storage reservoirs. Another biological control agent is a strain of the bacterium *Bacillus thuringiensis* (Bt), which occurs naturally in the soil and on plants. Different varieties of this bacterium produce a crystalline protein that is toxic to specific groups of insects. The variety *israelensis* is used to control mosquitoes, black flies, and fungus gnat larvae.

FIGURE 4-2

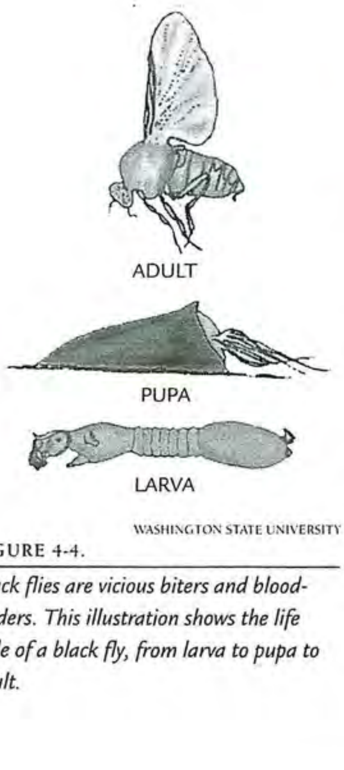
CDFA PHOTO

Mud pumps are one means used to clean out drainage ditches to destroy mosquito breeding areas.

JACK KELLY CLARK

FIGURE 4-3.

The mosquitofish (Gambusia affinis) *is an effective biological control agent for mosquito larvae.*



WASHINGTON STATE UNIVERSITY

FIGURE 4-4.

Black flies are vicious biters and blood-feeders. This illustration shows the life cycle of a black fly, from larva to pupa to adult.

WASHINGTON STATE UNIVERSITY

FIGURE 4-5.

Adult midges are sometimes called no-see-ums or punkies. They are small in size but have a vicious bite.

Black Flies

Black flies belong to the Diptera family Simuliidae and are related to other flies, mosquitoes, midges, and gnats. They are small, usually dark-colored insects, with short legs, broad wings, and a humpbacked appearance (Figure 4-4). Their eggs, larvae, and pupae inhabit water. Like mosquitoes, black flies are biters and blood-feeders. They thrive in clean, fast-flowing streams and rivers. They often attach their larval cases to concrete canal linings and conduits.

In California and other parts of the United States black flies are sometimes considered serious aquatic pests of resort areas because of their biting. Adult black flies are most common in May and June and may emerge in very large numbers.

Midges

Midges (Figure 4-5) are small flying insects that closely resemble mosquitoes. They inhabit weedy waters and feed on plants and decaying matter. Adults of some species bite, attacking people and other large mammals such as deer, dogs, and livestock. Adults of some of the biting species can vector parasitic worms that cause diseases in humans and other animals. The biting midge *Culicoides varipennis* spreads the bluetongue virus among livestock. Adults of nonbiting species are pests only when they swarm in very large numbers to mate during summer months. Midges lay their eggs in water, in moist ground, or on decaying matter, and larvae provide an important food source for many freshwater fish.

Nuisance Insects

Dobsonflies and caddisflies spend their immature life stages in fresh water. In spite of their common names, they are not true flies and are not related to the mosquitoes, black flies, and midges described above. In the larval and pupal stages, they attach to rocks, logs, and other structures. Heavy infestations in pipelines may decrease water flow capacity.

Dobsonflies. Dobsonflies belong to the insect order Neuroptera. Adult dobsonflies are 2 to 4 inches long, soft-bodied, and usually have brownish wings with many cross veins. A white

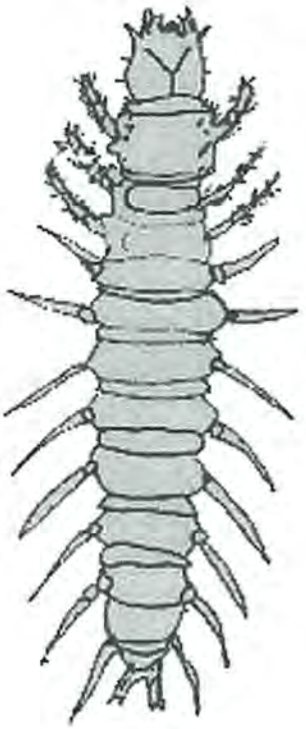


FIGURE 4-6.

Dobsonfly larvae, or hellgrammites, live in fast-flowing, shallow streams.

dot is visible on each cell of the wings. The adults live near water and are attracted to light. The larvae, known as hellgrammites (Figure 4-6), live in fast-flowing, shallow streams for approximately 3 years before reaching adulthood. They feed on small aquatic organisms. Hellgrammites have powerful jaws and may inflict painful bites on people.

Caddisflies. Caddisflies belong to the insect order Trichoptera. Immature caddisflies live in cold-running fresh streams and in ponds. Larval caddisflies are bottom dwellers and live in cases they construct from sticks, gravel, or sand. In large numbers these insects can disrupt flowing water and clog outlets (Figure 4-7). Larvae of some species occupy old snail shells or hollow reeds. The larvae range from $\frac{1}{12}$ inch to nearly 2 inches in length. Their bodies have hooked ends and they have three pairs of legs.

Adult caddisflies resemble moths, but unlike moths, caddisflies have long antennae without hairs. When they are at rest, their wings form a tentlike roof over the length of the body. They sometimes have stringlike gills on their abdomen, and they lay their eggs, which are often bright green, in strands or clusters.

FIGURE 4-7.

Larval caddisflies are bottom dwellers and build and live in cases made of sticks, gravel, or sand that can disrupt flowing water and clog outlets.

Crabs

Crabs are arthropods that belong to the class Crustacea, the crustaceans. These aquatic animals are related to lobsters and crayfish. Most crabs are not considered pests, and many species are caught for food. The recently introduced Chinese mitten crab, however, has become a serious pest in California's waterways.

Chinese Mitten Crab

The Chinese mitten crab (*Eriocheir sinensis*, Figure 4-8), is native to mainland China and coastal areas along the Yellow Sea. These crabs were first observed in the South San Francisco Bay in 1992. They quickly spread to San Pablo and Suisun Bays and the Sacramento-San Joaquin Delta. Mitten crabs grow and develop in fresh water and then travel to salt water to reproduce. In tidal areas, juvenile crabs burrow into levees and banks. Although they burrow no deeper than 12 inches, a large number of burrows may weaken levees. The Chinese mitten crab is a nuisance to sport anglers, because adult crabs steal bait. Large

FIGURE 4-8. GARY GOLDSMITH, *FAIRFIELD DAILY REPUBLIC*

The Chinese mitten crab grows and develops in fresh water and then travels to salt water to reproduce.

numbers of these crabs pose an economic threat to crayfish and bay shrimp fisheries. In Asia, the Chinese mitten crab is a nuisance in rice fields, and since its introduction into California, it threatens rice culture in the Sacramento Valley.

Chinese mitten crabs are widely distributed throughout the Central Valley watershed. Juveniles are especially abundant in freshwater areas in the South San Francisco Bay, where clay banks are lined with bulrushes. In the Sacramento River Delta, there is preliminary evidence that they also reproduce in waterhyacinth and in submersed aquatic vegetation, including egeria. Concrete-lined flood control channels and limited supplies of fresh water in some areas of California may limit their distribution.

FIGUE 4-9. U.S. ARMY CORPS OF ENGINEERS

Zebra mussels, major pests in the Midwest and eastern United States, are considered a major threat to California waters. They have been found on trailered boats at some agricultural inspection stations on the borders of California, but none have been found in the state's waters as of March, 1999.

Mollusks

Mollusks are invertebrates with soft, unsegmented bodies, usually enclosed in shells. Snails, freshwater clams, and mussels are members of this group, the phylum Mollusca. Clams and mussels inhabit many irrigation systems.

Zebra mussels (*Dreissena polymorpha*, Figure 4-9) are major aquatic pests in the Midwest and in the eastern United States. Ships from the Caspian Sea unintentionally released the hitchhiking pest into the Great Lakes area where they were first sighted in Lake St. Claire, Wisconsin, in 1988. There is great concern that the zebra mussel will manage to infiltrate California waters. Since 1993, this invasive pest has been intercepted on trailered boats at California's agricultural quarantine stations.

Clams

Asiatic Clam. The freshwater Asiatic clam (*Corbicula fluminea*) (Figure 4-10) burrows into the sediment and feeds on plankton and other food sources carried to it by the surrounding water. The larvae are very small, soft-bodied, and easily transported by water. Especially a problem for water utility companies, Asiatic clams clog pipelines, valves, screens, and meters. They damage centrifugal pumps and cause taste and odor problems in the water. In California and other western states, the Asiatic clam infests irrigation canals and major rivers. The clam was first recorded in California in 1945 in the Sacramento-San Joaquin Delta.

Asian Clam. The introduced Asian clam (*Potamocorbula amurensis*) was first detected in California in 1986. It is salt-tolerant and highly invasive and has drastically changed the ecology of the Suisun, San Pablo, and San Francisco Bays. Its unintentional introduction into the San Francisco Bay resulted in a ten-fold reduction of phytoplankton levels within a 2-year period, significantly altering the food chain.

Snails

Like clams and mussels, snails belong to the phylum Mollusca. Some aquatic snails are carriers of a minute, free-swimming parasitic larva that burrows into human skin. Irritation caused by this parasite is known as "swimmer's itch." The parasite is a member of the phylum Platyhelminthes, which includes flatworms, flukes, and tapeworms.

VERTEBRATE PESTS

Vertebrates are animals that have internal skeletons and backbones, such as fish, amphibians, mammals, and

U.S. ARMY CORPS OF ENGINEERS

FIGURE 4-10.

Asiatic clams clog water pipelines, valves, screens, and meters and may damage pumps.

birds. Only a few vertebrates in aquatic settings are considered pests or nuisances. They become pests when they cause economic or environmental damage, or create human health or safety hazards. For example, bird feces may pollute drinking water resources. Some animals damage or weaken the banks of levees and reservoirs. Others prey on or outcompete more desirable vertebrates.

Generally, the U.S. Fish and Wildlife Service, part of the U.S. Department of the Interior, is responsible for migratory birds, federal endangered species, and marine mammals. The California Department of Fish and Game maintains jurisdiction over inland fish, resident birds, and mammals, including state-listed endangered species. These agencies are primarily conservation-oriented, but they also regulate fishing, hunting, fur trapping, and similar activities. Therefore, just as you need permission to fish, hunt, and trap, you must also obtain permission to control or manage vertebrates in and around aquatic areas.

If you have a vertebrate problem in an aquatic setting, contact the California Department of Fish and Game. For information on endangered species laws and ways to protect these plants or animals, check with the nearest Endangered Species Office of the U.S. Fish and Wildlife Service or the local or regional office of the California Department of Fish and Game.

Fish

Most of the estimated 120 native and exotic fish species in California serve useful purposes. However, exotic and native species may be pests in some situations, depending on particular characteristics of the species or its interaction with other animals.

The major reason certain fish become pests is that they adversely affect other fish species or spoil the body of water in which they occur. Their impact may be direct, through predation or competition, or indirect, by destroying the aquatic habitat or degrading water quality. Occasionally, fish such as bluegills overpopulate a body of water and become stunted. Catfish can become pests when they clog water intake lines. Rough fish, including suckers and hardheads, are capable of taking over trout streams.

Fish that are unwanted in a specific location or that interfere with the intended economic, recreational, or aesthetic uses of the water may be considered pests. Exotic fish, such as Northern pike, are more likely to be pests. Other species of fish that may become pests include carp, goldfish, grass carp (Figure 4-11), white bass, and hitch.

Exotic fish are not always considered pests. Striped bass and brook trout were introduced from the eastern United States and are considered valuable sport species. However, these introduced sport species become pests if they prey on or out-compete native aquatic species. For example, brook trout populations in some Sierra Nevada streams threaten the Lahontan cutthroat trout, an endangered native species. In these cases, the brook trout populations must be managed to protect native fish.

Amphibians

Amphibians include salamanders, newts, frogs, and toads. Very few of the approximately 40 species of amphibians found in California are aquatic pests. Generally, amphibian species are important in freshwater and terrestrial habitats. However, some are pests in certain situations.

The major amphibian pest in California is the bullfrog (*Ranta catesbeiana*), introduced into California in the 1800s from the eastern United States. The bullfrog is an important predatory threat to fish, including bass, sunfish, and bluegills. In some cases, particularly in small ponds on private land, the bullfrog impact on game fish may become so significant that the pond owner must implement control measures.

IMPERIAL COUNTY IRRIGATION DISTRICT

FIGURE 4-11.

Grass carp may become problems when they are unwanted in a specific location or threaten the intended use of the water.

GREG KEARNS, U.S. DEPARTMENT OF THE INTERIOR

FIGURE 4-12.

California regulations prohibit the import of nutrias due to their potential damage to aquatic ecosystems. Nutrias look somewhat like beavers but have ratlike tails.

Bullfrogs also prey on other amphibians and can upset aquatic ecosystems. For example, a bullfrog invasion of the South Fork of the Eel River in Mendocino County in the mid 1990s led to a decrease of yellow-legged and red-legged frogs. Bullfrogs are also considered an important predatory threat to the California freshwater shrimp (*Syncaris pacifica*), an endangered species found only in a few small streams north of San Francisco.

Fish and wildlife management agencies that have the proper legal authority and technical expertise conduct most fish or amphibian pest control projects. Occasionally, however, individuals may want to conduct aquatic vertebrate pest control activities on privately owned land. The California Department of Fish and Game can provide further information and determine what restrictions or regulations apply and what permits are needed.

Mammals

A few mammals become pests in aquatic environments. These include the burrowing semiaquatic beaver and the muskrat. The introduced Norway rat, although not semiaquatic, is considered a pest of aquatic environments since it is frequently associated with water and causes damage similar to that of muskrats. The pocket gopher and ground squirrel are other mammals of concern, not because they prefer aquatic environments, but because they burrow into earthen dams, levees, and canal embankments. Their extensive burrows, like those of beavers and muskrats, undermine the integrity of these structures, creating the potential for major breaks.

Nutrias. In certain other states, the introduced semiaquatic nutria (Figure 4-12) is also a pest. Fortunately, state agencies have managed to eliminate the few of these large burrowing rodents that were deliberately and illegally released, and it is believed that none presently occur in California. The state prohibits nutrias due to their potential for aquatic ecosystem degradation and agricultural damage. If you ever see what you believe to be a nutria, report it immediately to the county agricultural commissioner in the county where you saw it, the California Department of Food and Agriculture, or the California Department of Fish and Game. Nutrias look somewhat like beavers but have ratlike tails.

Beavers. Beavers are the largest rodents in North America. They cut trees (Figure 4-13), build dams to impound water, and burrow into embankments. Their dams impede water flow, and the burrowing causes levee breaks. Unchecked, beavers can seriously and permanently damage levees.

The control of beavers is best left to professionals who are familiar with their management and habits. Destroying beaver dams is rarely a solution, since the beavers simply rebuild. However, specially designed plug-free culverts can be placed through the dams to help maintain the water level at an acceptable level. Sturdy beaver-proof fences or trunk-protecting barriers around individual trees protect

JACK KELLY CLARK

FIGURE 4-13.

The beaver damage shown here demonstrates why beavers can be pests.

orchard, ornamental, shade, and other desirable trees from beaver damage.

Muskrats. Muskrats (Figure 4-14) are semiaquatic rodents that are considerably smaller than beavers. They are distinguished by their hairless, vertically flattened, rudderlike tail and webbed hind feet. Like beavers, they need to live near water. Muskrats occur in most of the state, but are most numerous in the Central Valley lowlands. They spend much of their time in the water feeding on aquatic vegetation. Their burrowing habits damage earthen dams and levees. They dig these burrows into banks at the water's edge, with the main entrances generally below the waterline.

FIGURE 4-14.

Muskrats spend much of their time feeding on aquatic vegetation. Their burrowing habits cause problems in aquatic ecosystems.

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Norway Rats. Norway rats (Figure 4-15) are introduced rodents that often prefer to live close to bodies of water where they have ready food resources. They burrow into banks along the water's edge and feed on various aquatic animals such as crayfish, snails, and shellfish. Norway rats are pests in aquatic environments because of their burrowing activities and because they contribute to the degradation of water quality and to public health problems.

Pocket Gophers. Pocket gophers (Figure 4-16) are native burrowing rodents. Their name is derived from their fur-lined cheek pouches. They live most of their lives in extensive underground burrow systems and feed primarily on succulent plant roots. Their burrowing activities in levees, canal embankments, and earthen dams make them pests. However, they rarely infest levees and earthen dams that are kept free of vegetation. Gophers always burrow well above the waterline on the embankments nearest the water. On the opposite side, away from the water,

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FIGURE 4-15.

Norway rats cause problems when they burrow into banks along the water's edge.

JACK KELLY CLARK

FIGURE 4-16.

Pocket gophers are pests in the aquatic environment because their burrows weaken or cause damage to earthen levees, canal embankments, or dams.

they burrow anywhere on the earthen structure. Their feeding burrows may be relatively shallow, but nest and food storage chambers are 6 feet or more deep. If gophers are left unchecked, they can riddle levees with underground tunnels. As water levels rise, water penetrates and the structures collapse.

In California pocket gophers are classified as nongame mammals. When they are causing damage they may be controlled at any time and in any unprohibited manner.

Ground Squirrels. Ground squirrels (Figure 4-17) are major rodent pests of rangeland and agricultural crops due to their voracious herbivorous appetites. These rodents are also of great concern in aquatic environments because they burrow into earthen levees, canal embankments, and dams. Their burrows can be from 4 to 6 inches in diameter and 40 to 80 feet in length, with numerous branches and exits. Burrow systems can be as deep as 6 feet.

The California Fish and Game Code classifies ground squirrels as nongame mammals. When they cause damage, they may be controlled by any unprohibited means. However, two species, the Mojave ground squirrel, *Spermo-*

KATHY KEATLEY GARVEY

FIGURE 4-18.

Waterfowl can become problems in aquatic environments and along shorelines, because they pollute the water and surrounding areas with their feces.

philus mohavensis, and the San Joaquin antelope squirrel, *Ammospermophilus nelsoni*, both with a limited distribution in California, are classified as rare by the California Department of Fish and Game and are protected. Before conducting ground squirrel control, check with your county agricultural commissioner's office to determine if a protected animal species might be present.

Birds

Birds are pests in some aquatic environments when their feces foul or degrade water quality and when polluted waters become a public health issue. Problem species include geese, ducks, coots, and gulls (Figure 4-18), which are all closely associated with water.

Fish-eating birds, such as great blue herons, gulls, and belted kingfishers, often become pests at aquaculture facilities. These predatory birds can cause considerable economic loss.

Birds that are considered to be pests in aquatic settings are almost always migratory birds protected by the U.S. Fish and Wildlife Service, which issues permits to control these birds only if the situation meets specific criteria.

FIGURE 4-17. JACK KELLY CLARK

Ground squirrels are of great concern in aquatic environments due to their burrowing activities.

SAFEGUARDING ENDANGERED SPECIES

Be sure you know which animal species are present on or near the property where you plan to use control methods that might endanger them. You also must know which control methods are prohibited within range of any endangered species. For example, laws may restrict the use of rodenticides in areas inhabited by certain endangered vertebrates.

Your local county agricultural commissioner's office maintains detailed maps showing the location of all endangered species. Officials can advise you on steps to follow prior to controlling a specific vertebrate pest. A list of endangered species in California and their locations is on the Department of Pesticide Regulation website, *http://www.cdpr.ca.gov/*.

REVIEW QUESTIONS

(answers on page 145)

1. Which one of the following is the most troublesome pest in the aquatic environment?

- ☐ a. Weeds
- ☐ b. Animals
- ☐ c. Parasites
- ☐ d. Insects

2. Besides annoying people and livestock, some mosquitoes are pests because they:

- ☐ a. Are attracted to lights at night
- ☐ b. Transmit organisms that cause malaria, encephalitis, or other human diseases, and canine heartworm
- ☐ c. Impede water flow
- ☐ d. Clog hydraulic systems

3. Swimmer's itch is caused by:

- ☐ a. Asiatic clams
- ☐ b. Blood-sucking leeches that inhabit certain bodies of water
- ☐ c. Parasitic larvae transmitted by snails
- ☐ d. Black fly larvae that burrow into human skin

4. The most effective mosquito control efforts involve:

- ☐ a. Spraying adults with insecticides
- ☐ b. Draining or eliminating the breeding areas
- ☐ c. Using biological control agents, such as mosquitofish
- ☐ d. Using mosquito nets

5. Which of the following insects are bottom dwellers and build and live in cases made of sticks, gravel, or sand?

- ☐ a. Sandflies
- ☐ b. Dobsonflies
- ☐ c. Caddisflies
- ☐ d. Black flies

6. The Asiatic clam is an aquatic pest because it:

- ☐ a. Transmits the swimmer's itch organism
- ☐ b. Infests irrigation canals and major rivers
- ☐ c. Spreads disease organisms
- ☐ d. Fouls the water

7. If you have a vertebrate problem in an aquatic setting, before taking control measures you should first contact:

- ☐ a. A University of California farm advisor
- ☐ b. The wildlife and fisheries department of a local university
- ☐ c. The California Department of Fish and Game
- ☐ d. A local wildlife agency

8. Which is the lead agency for protecting and managing the state's diverse fish and wildlife resources?

- ☐ a. The California Department of Food and Agriculture
- ☐ b. The National Wildlife Association
- ☐ c. The California Department of Fish and Game
- ☐ d. Local county agricultural commissioners' offices

9. Muskrats are pests primarily because they:

- ☐ a. Eat aquatic vegetation
- ☐ b. Burrow into banks and levees
- ☐ c. Cut down trees
- ☐ d. Frighten other vertebrates

10. Birds are pests in an aquatic environment primarily because they:

- ☐ a. Contaminate the water with their feces
- ☐ b. Consume large numbers of fish
- ☐ c. Destroy aquatic vegetation
- ☐ d. Transmit the organism that produces cholera

5 Handling Pesticides Safely

JACK KELLY CLARK

A large tank opening allows you to mix pesticides more safely.

PESTICIDES ARE IMPORTANT TOOLS for controlling weeds, insects, and other pests in aquatic environments. Handling pesticides safely and effectively means using them according to label instructions and following all state and local regulations. If you misuse or improperly handle any pesticides you could be creating serious hazards to people, nontarget organisms, and the environment.

Minimize pesticide hazards by

- selecting the least toxic pesticides whenever possible
- applying pesticides at times when pests are the most vulnerable
- protecting yourself with label-specified personal protective equipment
- mixing, loading, and applying pesticides according to label directions (Figure 5-1)
- disposing of containers and rinsates in approved ways
- storing pesticides and pesticide containers in designated and locked areas

The information you need to handle pesticides safely and legally is on the pesticide label and associated labeling, so read and understand this information and follow all directions. It is illegal to do otherwise. Also, California has established additional pesticide use and handling requirements that might not be on many pesticide labels. For instance, California's minimal personal protective equipment requirements may exceed label requirements (Sidebar 12 and Figure 5-2). For comprehensive information on handling and applying pesticides, see the chapters "Hazards Associated with Pesticides Use," "Protecting People and the Environ-

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FIGURE 5-1.

Follow label directions and observe all warnings and precautions when mixing and applying pesticides.

SIDEBAR 12

California's Minimum Personal Protective Equipment Requirements

California has additional personal protective equipment (PPE) requirements that may not appear on the labels of pesticide products. However, pesticide labels may be more restrictive than the requirements listed here. Always follow the requirements that provide the greatest protection.

EYE PROTECTION

Eye protection includes safety glasses (with front, brow, and temple protection), goggles, a face shield, or a full-face mask. These are all considered PPE, and any of these types may be worn unless the label gives specific requirements. Regular eyeglasses or sunglasses are not safety glasses. You must wear eye protection not only when the label instructions specify that you must, but also when

- ☐ mixing and loading any pesticide
- ☐ adjusting, cleaning, or repairing pesticide-handling equipment
- ☐ applying pesticides on the ground or from boats, except when injecting or incorporating pesticides into the soil, working in an enclosed cab, or when spray nozzles are located below you and are pointed downward
- ☐ applying pesticides by hand, except when applying vertebrate baits, baiting insect monitoring traps, or applying non-insecticidal lures

GLOVES

Wear waterproof, chemical-resistant gloves when

- ☐ mixing and loading any pesticide
- ☐ adjusting, cleaning, or repairing pesticide-contaminated equipment
- ☐ applying pesticides by hand (except when applying vertebrate pest control products and using long-handled tools)

COVERALLS

Unless the label requires additional protection, wear a clean coverall (a one- or two-piece garment with long sleeves and long pants) when applying pesticides whose labels contain the signal word *Warning* or *Danger*.

FOOTWEAR

Shoes and socks are the minimal foot protection required for any pesticide handling situation. Labels may specify waterproof boots or waterproof boots may be substituted for shoes and socks.

CDFA PHOTO

FIGURE 5-2.

The pesticide label tells what specific articles of personal protective equipment are required to be worn when handling the pesticide.

FIGURE 5-3.

Sample aquatic herbicide label.

RESTRICTED USE PESTICIDE

Due to High Acute Toxicity to Humans

9 — For retail sale and use only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification. Direct supervision for this product requires the certified applicator to review federal and supplemental label instructions with all personnel prior to application, mixing, loading, or repair or cleaning of application equipment.

1 — **Reckon® AQUA**

herbicide by **ToxCo®**

5 — Active Ingredient:	*By Weight*
3 — Endothall	
2 — 7-oxabicyclo [2.2.1]heptane-2,3-diacarboxylic acid equivalent	29%
Inert Ingredients:	71%
TOTAL	100%

4 — **Water Soluble Liquid**

Contains 4.2 lbs active ingredient per gallon.

8 — EPA Reg. No. 000-000

EPA EST. No. 0000-XX-0

6 — Net 5 gallons

KEEP OUT OF REACH OF CHILDREN

10 — DANGER POISON

PELIGRO VENENO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

STATEMENT OF PRACTICAL TREATMENT

If swallowed: drink promptly a large quantity of milk, egg whites, gelatin solution, or if these are not available, drink large quantities of water. Avoid alcohol. Call a phyician immediately.
If in eyes: hold eyelids open and flush with a steady gentle stream of water for 15 minutes. Get medical attention.
If on skin: immediately flush with plenty of water for at least 15 minutes. Remove and wash contaminated clothing before reuse.
NOTE TO PYSICIAN: Probable mucosal damage may contraindicate the use of gastric lavage. Measures against circulatory shock, respiratory depression, and convulsion may be needed.
For medical emergencies involving this product, call toll free 1-000-000-0000.

11 — PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS AND DOMESTIC ANIMALS

DANGER! FATAL IF ABSORBED THROUGH SKIN. MAY BE FATAL IF SWALLOWED. HARMFUL IF INHALED. CORROSIVE, CAUSES IRREVERSIBLE EYE DAMAGE. DO NOT GET IN EYES, ON SKIN, OR ON CLOTHING. WEAR PROTECTIVE CLOTHING, RUBBER GLOVES, AND GOGGLES OR FACE SHIELD WHEN HANDLING. Wash thoroughly with soap and water after handling and before eating or smoking. Remove contaminated clothing and wash before reuse. Avoid breathing spray mist.

(Precautionary Statements continued in next column.)

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PERSONAL PROTECTIVE EQUIPMENT

Some materials that are chemical-resistant to this product are listed below. If you want more options, follow the instructions for category B on an EPA chemical-resistance category selection chart.

Applicators and other handlers must wear:
Long-sleeved shirt and long pants.
Chemical-resistant gloves, such as barrier laminate or butyl rubber.
Shoes plus socks.
Protective eyewear.
For exposure in enclosed areas, a respirator with either an organic vapor-removing cartridge with a prefilter approved for pesticides (MSHA/NIOSH approval number prefix TC-23C or a NIOSH-approved respirator with any R, P, or HE filter [also N if product does not contain oil and bears no instructions that will allow application with an oil-containing material]), or a canister approved for pesticides (MSHA/NIOSH approval number prefix TC-14G).
For exposures outdoors, dust/mist filtering respirator (MSHA/NIOSH approval number prefix TC-21C or a NIOSH-approved respirator with any R, P, or HE filter [also N if product does not contain oil and bears no instructions that will allow application with an oil-containing material]).

Cleaners and repairers of application equipment must wear:
Long-sleeved shirt and long pants.
Chemical resistant gloves.
Chemical resistant footwear.
Protective eyewear.
Respirator as outlined above.
Chemical resistant apron.

Discard clothing or other absorbent materials that have been drenched or heavily contaminated with this product's concentrate. Do not reuse them. Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

GENERAL INFORMATION

RECKON AQUA is a liquid concentrate soluble in water that is effective against a broad range of aquatic plants with a margin of safety to fish.

Dosage rates indicated for the application of RECKON AQUA are measured in "Parts Per Million" (ppm) of dipotassium endothall. Only 0.5 to 5.0 ppm are generally reuired for aquatic weed control, wheras some fish species are tolerant to approximately 100 ppm or over.

ENVIRONMENTAL HAZARDS

Avoid contact with or drift to other crops or plants as injur may result. Wash out spray equipment with water after each operation.

Do not use fish from treated areas for food or feed within 3 days of treatment.Do not use water from treated ares for watering livestock, for preparing agricultural sprays for food crops, for irrigation, or for domestic purposes within the following periods:

Up o 0.5 ppm dipotassium salt
(0.35 ppm acid equivalent)—7 days after application

Up to 4.25 ppm dipotassium salt
(3.0 ppm acid equivalent)—14 days after application

Up to 5.0 ppm dipotassium salt
(3.5 ppm acid equivalent)—25 days after application

NOTE: Areas treated with RECKON AQUA may be used for swimming twenty-four hours after treatment.

PHYSICAL AND CHEMICAL HAZARDS

Combustible. Do not use or store near heat or open flame. Keep container closed. Use with adequate ventilation.

DIRECTIONS FOR USE

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

AQUATIC WEEDS CONTROLLED AND DOSAGE RATE CHARTS

RECKON AQUA is recommended for the control of the following aquatic weeds in irrigation and drainage canals, ponds, and lakes at the rates indicated. Since the active ingredient is water-soluble and tends to diffuse from the area treated, select the dosage rate applicable to the area to be treated. Use the lower rate in each range of rates where the growth is young and growing and/or where the weed stand is not heavy. Marginal treatments of large bodies of water require higher rates as indicated.

HOW TO APPLY:

RECKON AQUA is a contact killer; consequently, do not apply before weeds are present. Application as early as possible after weeds are present is recommended to permit use of lower application rates. However, for best results, water temperature should be at 65°F or above. If an entire pond is treated at one time, or if the dissolved oxygen level is low at time of application, decay of weeds may remove enough oxygen from the water, causing fish to suffocate. Water containing very heavy vegetation should be treated in sections to prevent suffocation of fish. Sections should be treated 5-7 days apart. Carefully measure size and depth of area to be treated and determine amount of RECKON AQUA to apply from chart. For best result, apply on a calm day where there is little wave action.

RECKON AQUA should be sprayed on the water or injected below the water surface and should be distributed as evenly as possible. It may be applied as it comes from the container or diluted with water depending on the equpment. Some dilution will give better distribution.

In instances where the nuisance to be controlled is an exposed surface problem (i.e., some of the broad-leaved pond weeds) it is important to get good contact coverage utilizing the highest concentration (least water dilution) compatible with the type of equipment used so that even distribution is achieved.

Necessary approval and/or permits should be obtained in states where required.

STORAGE AND DISPOSAL

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

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Storage Instructions: Store in the original container. Do not store in a manner where cross-contaminion with other pesticides, fertilizers, food, or feed could occur. Storage at temperatures below 32°F may result in the product freezing or crystalizing. Should this occur, the product must be warmed to 50°F or higher and thoroughly agitated. In the event of a spillage during handling or storage, absorb with sand or other inert material and dispose of absorbent in accordance with the Pesticide Disposal Instructions listed below.

Pesticide Disposal Instructions: Pesticide wastes are acutely hazardous. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of federal law. If these wstes cannot be dispose of by use according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste representative at the nearest EPA Regional Office for guidance.

Container Disposal Instructions: Triple rinse (or equivalent), then offer for recycling or reconditioning if container reuse is permitted, or puncture and dispose of in a sanitary landfill, or by incineration, or, if allowed by state and local authorities, by burning. If burned, stay away from the smoke.

LIMITATION OF WARRANTY AND LIABILITY

NOTICE: Read This Limitation of Warranty and Liability Before Buying or Using This Product. If the Terms Are Not Acceptable, Return the Product at Once, Unopened, and the Purchase Price Will Be Refunded.
It is impossible to eliminate all risks associated with the use of this product. Such risks arise from weather conditions, soil factors, off target movement, unconventional farming techniques, presence of other materials, the manner of use or application, or other unknown factors, all of which are beyond the control of ToxCo. These risks can cause: ineffectiveness of the product or injury to nontarget crops or plants.

ToxCo does not agree to be an insurer of these risks. WHEN YOU BY OR USE THIS PRODUCT, YOU AGREE TO ACCEPT THESE RISKS.

COMMON NAME	LATIN NAME	ENTIRE POND OR LARGE AREA TREATMENT	SPOT OR LAKE MARGIN TREATMENT
Coontail	*Ceratophyllum* spp.	1.0 - 2.0 ppm	3.0 - 4.0 ppm
Hydrilla	*Hydrilla verticillata*	2.0 - 3.0 ppm	3.0 - 4.0 ppm
Milfoil	*Myriophyllum* spp.	2.0 - 3.0 ppm	3.0 - 4.0 ppm
Pondweed			
Bushy	*Najas* spp.	0.5 - 1.5 ppm	2.0 - 3.0 ppm
Curly-Leaf	*Potamogeton crispus*	0.5 - 1.5 ppm	2.0 - 3.0 ppm
Flat-Stem	*Potamogeton zosteriformis*	2.0 - 3.0 ppm	3.0 - 4.0 ppm
Floating-Leaf	*Potamogeton natans*	1.0 - 2.0 ppm	2.0 - 3.0 ppm
Horned	*Zannichellia* spp.	1.0 - 2.0 ppm	2.0 - 3.0 ppm
Sago	*Potamogeton pectinatus*	2.0 - 3.0 ppm	3.0 - 4.0 ppm

RATE OF APPLICATION—LAKES AND PONDS
The following chart indicates the total quantity of material to be applied.
APPROXIMATE GALLONS OF RECKON AQUA FOR A ONE-ACRE (208' x 208') TREATMENT

	DOSAGE IN GALLONS FOR VARIOUS CONCENTRATIONS IN PPM						
DEPTH	0.5 ppm	1.0 ppm	1.5 ppm	2.0 ppm	3.0 ppm	4.0 ppm	5.0 ppm
1 foot	0.3	0.6	1.0	1.3	1.9	2.6	3.2
2 feet	0.6	1.3	1.9	2.6	3.8	5.1	6.4
4 feet	1.3	2.6	3.8	5.1	7.7	10.2	12.8
6 feet	1.9	3.8	5.8	7.6	11.5	15.3	19.2

ment," "Pesticide Emergencies," and "Using Pesticides Effectively" in *The Safe and Effective Use of Pesticides, Second Edition.*

PESTICIDE LABELS AND ASSOCIATED LABELING

Pesticide labeling includes the label on the pesticide container, supplemental labels that are attached to the pesticide package, and other documents referred to on the label. These other documents include endangered species range maps, Worker Protection Standard provisions, and other documents that restrict how the pesticide can be used. The pesticide label and associated labeling are the primary means of communication between the manufacturer and the pesticide user. Remember that pesticide labels and all associated labeling are legal documents. Most violations of the instructions given in these documents are violations of the law and could subject you to fines and possible imprisonment. Be sure that the pesticide label specifies *for aquatic use.*

The parts of a pesticide label are explained below. While you are reading this section, refer to the sample label, Figure 5-3, on pages 96 and 97.

Brand Name. 1. A brand name is the name the manufacturer gives to the product. This is the name used for all advertising and promoting.

Chemical Name. 2. Chemical names describe the chemical structure of a pesticide. Chemists follow international rules for naming chemicals.

Common Name. 3. Chemical names of pesticide active ingredients are often complicated. Therefore, manufacturers give most pesticides *common* or generic names. For example, *0,0-diethyl 0(2-isopropyl-6-methyl-4-pyrimidinyl)* has the common name *diazinon*. Common names and brand names are not the same and not all labels list common names for the pesticide.

Formulation. 4. Labels usually list the formulation type, such as emulsifiable concentrate, wettable powder, or soluble powder. Manufacturers may include this information as a suffix in the brand name of the pesticide, such as 50 WP. This 50 means that 50% of the wettable powder formulation is the active ingredient.

Always be aware of the formulation type before buying a product. Different formulations may contain the same active ingredient but might be used to control different weeds. For example, for the fictitious pesticide Weed-B-Gone, there may be a Weed-B-Gone AS (aqueous suspension), Weed-B-Gone SP (soluble powder) and a Weed-B-Gone SRP (slow release pellet). Weed-B-Gone AS might be used to spray common duckweed, a floating aquatic weed, whereas Weed-B-Gone SP and SRP might be used to control submersed weeds such as coontail and egeria. The way a pesticide is formulated also influences its potential for harming people, nontarget organisms, and the environment.

See Table 5-1 for formulations used in aquatic herbicide products.

Ingredients. 5. Pesticide labels list the percentage of active and inert ingredients by weight. Inert ingredients are components of the formulation that do not have pesticidal action. However, these may be toxic, flammable, or pose other health, safety, or environmental problems. Some, however, are harmless, such as clay. If a pesticide contains more than one active ingredient, the label may state the percentage of each. Sometimes manufacturers group all inert ingredients together, and their labels do not show the percentage of each one.

TABLE 5-1.

Common Formulations Used in Aquatic Herbicide Products.

FORMULATION	TYPE	DESCRIPTION
AS	aqueous suspension	Low-solubility herbicides suspended in water on a carrier such as fine clay particles. Adjuvants may be added to keep the herbicide and carrier in suspension. Requires agitation.
S	soluble concentrate	A concentrated material that dissolves completely in water. Agitation not required.
EC	emulsifiable concentrate	Emulsifiable concentrates are a mixture of petroleum solvents and emulsifiers that permit mixture with water. Requires agitation.
F	flowable	Insoluble solid-phase material suspended in a liquid. Active ingredients are insoluble in water and form suspensions when mixed with water. Requires agitation.
DF	dry flowable	Insoluble in water, but can be formulated to be easily poured and measured. Easier to handle than wettable powders, but usually more expensive. Requires agitation.
G or P	granular or pellet	Active ingredient is usually mixed into or sprayed onto clay particles. The amount of active ingredient typically ranges from 1 to 15%. Used for submersed weeds; ineffective as a foliar treatment. Can be expensive per pound.
WP	wettable powder	A fine dust of insoluble material that forms a suspension when mixed with water. Low cost, ease of handling, ease of measuring. Suspended particles can be abrasive on spray equipment. Requires agitation.

Net Contents. 6. Labels list the net contents, by weight or liquid volume, contained in the package.

Manufacturer. 7. Pesticide labels always contain the name and address of the manufacturer of the product. Use this address if you need to contact the manufacturer for any reason.

Registration and Establishment Numbers. 8. The U.S. EPA assigns registration numbers to each pesticide. You need this EPA number if you are reporting the use of the pesticide. In addition, the establishment number identifies the site of manufacture or repackaging.

Statement of Use Classification. 9. The U.S. EPA classifies pesticides as either "General-Use" or "Restricted-Use." U.S. EPA *restricted-use pesticides* have a special statement printed on the label in a prominent place. Pesticides that do not contain this statement are *general-use pesticides*, except where special state restrictions apply. For information, check the DPR list *State Restricted-Use Pesticides*, available from county agricultural commissioners. Some labels have *restrictive statements* indicating that they are for agricultural or commercial use only. A restrictive statement is different from a statement of use classification.

Signal Words. 10. An important part of every label is the signal word. The words *Danger* and *Poison* (with skull and crossbones) indicate that the pesticide is highly toxic. The word *Danger* used alone indicates that the pesticide poses a dangerous health or environmental hazard. *Warning* indicates moderate toxicity, and

Caution means low toxicity. See Table 5-2 for an explanation of these different toxicity categories. Part of the registration process assigns each pesticide to a toxicity category. The level of hazard is a guide to help determine which signal word manufacturers must use on their labels.

Precautionary Statements. 11. Precautionary statements describe the pesticide hazards. Read and follow the instructions given in a precautionary statement. This section of the label includes as many as three areas of hazard. Most important are the *hazards to people and domestic animals*. This part tells why the pesticide is hazardous and lists adverse effects that may occur if people become exposed. It describes the type of protective equipment to wear while handling packages and during mixing and applying.

The second part of a precautionary statement describes environmental hazards. It tells you if the pesticide is toxic to nontarget organisms such as honey bees, fish, birds, and other wildlife. Here is also where you get information on how to avoid environmental contamination.

The third part of the precautionary statement explains special physical and chemical hazards. These include risks of fire or explosion and hazards from fumes.

Directions for Use. 12. The directions for use are an important part of the pesticide label. It is a violation of the law if you do not follow these instructions. The only exceptions are cases where federal or state laws specify acceptable deviations from label instructions (see Sidebar 13). These instructions tell you how to apply the pesticide. They specify how much to use, where to use the material, and when to apply it.

The directions for use list all the target pests that manufacturers claim their pesticides control. They also include the aquatic sites or crops, plant species, animals, or other sites where you can use the pesticides. Here is where you find special restrictions that you must observe, including restrictions on feeding crop residues to livestock or grazing livestock on treated plants.

Some pesticide labels contain precautions about entering a treated area or using treated water after application. This statement may also tell you how much time must pass before people are allowed to swim in treated water and when the treated

TABLE 5-2.
Signal Words of Pesticide Toxicity Categories.

HAZARD INDICATORS →	HAZARD LEVELS		
	DANGER	*WARNING*	*CAUTION*
oral LD_{50}*	up to and including 50 mg/kg	from 50 to 500 mg/kg	greater than 500 mg/kg
inhalation LC_{50}*	up to and including 0.2 µ/liter (0–2,000 ppm)	from 0.2 to 2 µ/liter (2,000–20,000 ppm)	greater than 2 µ/liter (greater than 20,000 ppm)
dermal LD_{50}*	up to and including 200 mg/kg	from 200 to 2,000 mg/kg	greater than 2,000 mg/kg
eye effects	corrosive; corneal opacity not reversible within 7 days	corneal opacity reversible within 7 days; irritation persisting for 7 days	no corneal opacity; irritation reversible within 7 days
skin effects	corrosive	severe irritation at 72 hours	moderate irritation at 72 hours

*LD_{50} values represent milligrams (mg) of the pesticide per kilogram (kg) of body weight of the test animals. LC_{50} values represent the micrograms (µ) of pesticide per liter of air inhaled by the test animals.

SIDEBAR 13

Acceptable Deviations from Pesticide Label Directions

Sometimes regulations allow you to use pesticides in a manner that varies from label directions. These methods generally involve safer or less-disruptive uses of the pesticide. Following are the only label deviations allowed by California law. These exceptions may change at any time or may not apply in certain instances. Always check with DPR or your local agricultural commissioner before using a pesticide in any manner that varies from label directions.

DECREASE IN RATE PER UNIT TREATED

It is always possible to apply pesticides at a lower rate than the rate given on the pesticide label. However, be cautious about using lower rates. Sometimes using lower rates speeds up the development of pesticide resistance in the target organism. To avoid possible problems when using lower rates, check first with your local farm advisor. Under no circumstances can you legally increase the amount of pesticide you apply beyond the maximum label rates.

DECREASE IN THE CONCENTRATION OF THE MIXTURE APPLIED

Label instructions usually state the volume of water to use when preparing a spray mixture. It is always possible to use more water than this; however too much water may cause excessive dilution and runoff. This results in not enough of the pesticide getting to the target pest. In most cases, use only as much water as necessary to obtain thorough coverage. Be sure this is not less than what the label states.

INCREASE IN CONCENTRATION AS LONG AS IT CORRESPONDS WITH PUBLISHED RECOMMENDATIONS OF THE UNIVERSITY OF CALIFORNIA

There are times when it would be convenient to use a more concentrated mixture than the dilution rate specified on the label. Although you would apply no more than the labeled rate of pesticide, you would prefer using less water in the mixture. If there are current, published UC guidelines for doing this, you can increase the concentration. However, these guidelines are pesticide-specific. Comply with all other label instructions. Remember, verbal recommendations of any type are not acceptable.

APPLICATION AT A FREQUENCY LESS THAN SPECIFIED

Label instructions often prescribe how often to apply a pesticide. Manufacturers recommend this frequency to maintain adequate control of the pest being treated. It is permissible under the law to make applications less frequently than the label recommends. If your monitoring confirms that less-frequent applications adequately control pests, there is no need to make additional treatments. It is never permissible to apply a pesticide more frequently than the interval listed on the label.

USE TO CONTROL A TARGET PEST NOT ON THE LABEL WHEN THE COMMODITY OR SITE IS ON THE LABEL AND USE AGAINST AN UNNAMED PEST IS NOT EXPRESSLY PROHIBITED

You may wish to use a pesticide on a commodity or site listed on the label, but the label does not list the target pest. As long as the label does not *forbid* use of this pesticide against the pest on the commodity or site, you may use it. Be certain the label lists the commodity or target site (for other pests). Follow all other label instructions.

USE OF ANY METHOD OF APPLICATION NOT PROHIBITED, PROVIDED OTHER LABEL DIRECTIONS ARE FOLLOWED

Most label recommendations do not specify exactly how to apply the pesticide. Should this be the case, it is possible to use any practical method. However, be sure the method you choose allows you to follow all other label directions. Applying a pesticide by ground or by air is an example. If there is no prohibition against aerial application on the label, you may use either method. However, you must comply with all label directions. (It may not be possible to apply a pesticide by air when the label prohibits the lower dilution rate required for aerial application.)

MIXING WITH ANOTHER PESTICIDE, UNLESS PROHIBITED

You may want to combine a pesticide with one or several others. This type of application saves time and reduces application costs. Unless specifically prohibited by directions on any of the labels, it is permissible to apply pesticides in combination.

EXCEPTIONS TO OR SUBSTITUTIONS FOR PERSONAL PROTECTIVE EQUIPMENT (PPE) REQUIREMENTS

State regulations provide for the following exceptions to some pesticide label PPE requirements:

- ☐ If you are using a closed system to handle pesticide products with the signal word *Danger* or *Warning*, you may substitute coveralls, chemical-resistant gloves, and a chemical-resistant apron for personal protective equipment required by the pesticide label.* Properly mixing pesticides packaged in water-soluble packets is considered to be using a closed system.
- ☐ If you use a closed system to handle pesticide products with the signal word *Caution*, you may substitute *work clothing* for the personal protective equipment required by the pesticide label.* Properly mixing pesticides packaged in water-soluble packets is considered to be using a closed system.
- ☐ If you are applying pesticides from an enclosed cab (including the cockpit of an aircraft), you may substitute work clothing for personal protective equipment required by the pesticide product labeling. If respiratory protection is required, you must wear this while applying pesticides from ground application equipment unless the cab is approved for respiratory protection.**
- ☐ You may substitute a chemical-resistant suit for coveralls and/or a chemical-resistant apron.
- ☐ If you are applying pesticides from an aircraft, you are not required to wear gloves during operation of the aircraft. However, wear gloves when entering or exiting if the aircraft is contaminated with pesticide residues. While in the cockpit, keep your gloves in a chemical-resistant container, such as a plastic bag.

*If the closed system you use operates under positive pressure, you must use protective eyewear. Also, have all personal protective equipment required by pesticide product labeling immediately available for use in an emergency.

**If you are working in an enclosed cab, other than an aircraft, you must have with you all personal protective equipment required by pesticide product labeling. Keep this PPE immediately available and store it in a chemical-resistant container, such as a plastic bag. Wear this label-required personal protective equipment if it is necessary to work outside the cab and contact pesticide-treated surfaces. Remove and store this PPE in a plastic bag before reentering the cab.

water may be used for irrigation or drinking.

Other information that may be found in the *directions for use* section of the label includes

- the type of application equipment to use
- how much pesticide to use
- mixing directions and whether the product can be mixed with other materials
- when, where, and how often the pesticide should be applied

This part of the labeling also contains instructions for storing the pesticide and how to properly dispose of excess pesticide and the pesticide container. These disposal instructions are acceptable under federal regulations, but in some cases state regulations may be more stringent or specific. For more information, consult the local county agricultural commissioner's office.

MATERIAL SAFETY DATA SHEETS

Material safety data sheets (MSDSs) provide additional information about the hazards associated with handling and storing pesticides. These documents are provided by the manufacturer and must be made available to anyone purchasing, storing, or handling pesticide products. Information covered on an MSDS includes: chemical product and company identification; information on the composition and physical and chemical properties of the ingredients; hazards and toxicology; first aid measures; fire fighting information; and steps to take to contain and clean up accidental releases. Other information covers handling and storage, ways to prevent exposure, impacts on the environment, disposal methods, requirements for transporting, and other regulatory requirements.

HOW PESTICIDES INJURE PEOPLE

Some pesticides cause illness or injury if they get onto the skin or into the eyes, or if dusts, droplets, or vapors are inhaled. Many pesticides are harmful if they are swallowed.

Most pesticide illnesses or injuries occur because handlers are not wearing the required personal protective equipment or fail to follow required handling procedures. Each year there are also a number of cases where people are injured by exposure to pesticides that have drifted from the application site because of an improper or careless application.

Routes of Exposure

Pesticides can contact or enter the body through the mouth, skin, eyes, and lungs (Figure 5-4). Generally, the most serious cases of pesticide poisoning occur when pesticides are swallowed. However, the most common types of exposure involve the skin and eyes.

Exposure to the Skin. Skin exposure accounts for more than 80% of the pesticide poisoning that occurs among

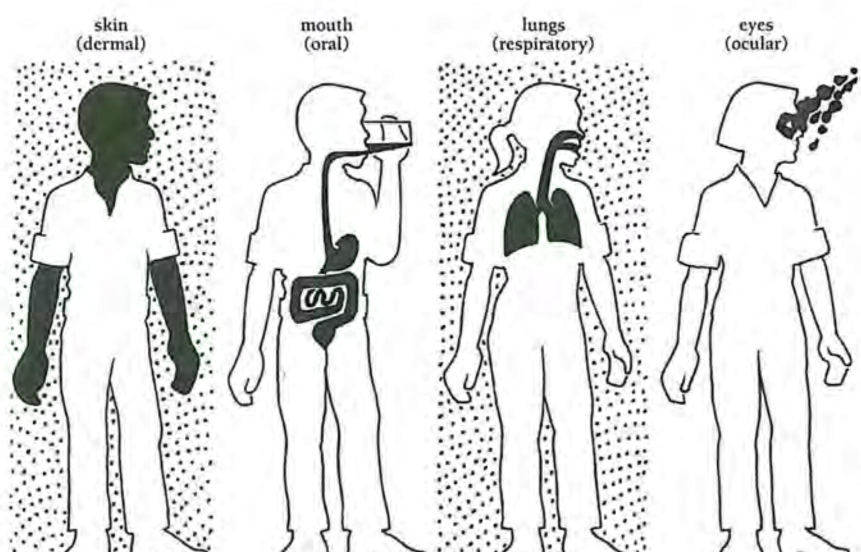

FIGURE 5-4.

The most common ways for pesticide exposure to occur are through the skin (dermal), through the mouth (oral), through the lungs (respiratory), and through the eyes (ocular).

handlers. The severity of this type of exposure depends on the pesticide, the length of time it remains on the skin, the amount of skin affected, and what part of the body received the exposure.

Exposure by Mouth. Accidentally swallowing pesticides is usually caused by carelessness or because someone put a pesticide into a food or beverage container. Eating, drinking, and smoking during or after handling pesticides can also result in some pesticide residue ingestion, unless the handler thoroughly washes with soap and water.

Inhalation Exposure. Inhalation exposure results from breathing spray mist, vapors, or dust. The risk of exposure is increased when you work in enclosed areas with poor ventilation or if you fail to wear the required respiratory protection.

Eye Exposure. The most common way eye exposure occurs is when the pesticide is splashed during mixing or handling. Ruptured hoses can also spray pesticides into the eyes. Wearing protective eyewear easily prevents eye injuries.

Toxicity

Toxicity, like color or boiling point, is one of the characteristics used to describe chemicals. Toxicity, sometimes referred to as *potency*, is the capacity of a chemical to cause injury. Most pesticides, by their nature, are toxic in order to destroy pests. Like other toxic chemicals, pesticides are hazardous because they have a potential for causing injury. Not all pesticides have the same hazard—some are more toxic or potent than others. The highly toxic pesticides cause injury at smaller doses and are therefore more hazardous.

Dose. Generally, the greater the quantity of a toxic chemical you are exposed to, the greater the risk of injury. The effect of a given dose varies from individual to individual, particularly with body size, age, and gender. An amount that has no effect on a 200-pound male adult could harm a 30-pound youngster. Infants and young children are normally affected by smaller doses than adults are. Females may have higher sensitivities to smaller doses than males.

Duration of Exposure. Generally, the longer the period of pesticide exposure, the more pesticide the body will absorb. How fast it is absorbed and how fast it is broken down and excreted varies from individual to individual. It also varies with the type of personal protective equipment worn and the type of pesticide.

Physical and Chemical Properties. Specific pesticides have qualities that affect the risk of exposure. For example, some pesticides evaporate more readily than others. Some break down quickly on the surface and react to sunlight, temperature, and wind. Some pesticides quickly pass through the skin.

Pesticide Poisoning Symptoms

Poisoning by some types of pesticides can cause symptoms such as skin rash, headache, or irritation of the eyes, nose, and throat. More severe cases of exposure to certain types of pesticides may cause blurred vision, dizziness, heavy sweating, weakness, nausea, stomach pain, vomiting, diarrhea, extreme thirst, or blistered skin. Exposure to some pesticides may also cause apprehension, restlessness, anxiety, unusual behavior, shaking, convulsions, or unconsciousness.

Certain pesticides can cause skin and eye irritation, and some produce allergic reactions. Symptoms can include redness, swelling, skin blistering, sneezing, itching, eye watering, or pimples.

FIRST AID FOR PESTICIDE POISONING

Appropriate first aid treatment for any pesticide exposure usually involves decontamination to eliminate or dilute the pesticide to prevent further injury. The label gives instructions on what to do in case of exposure. In addition, always have an emergency plan for obtaining medical treatment. Keep the name, address, and telephone number of the nearest emergency medical facility at the mixing site and on or near the application equipment.

General tips for immediate first aid are listed below but are not a substitute for medical attention and treatment. After you have administered first aid, seek medical aid if any symptoms or irritation persist.

Swallowed Pesticides. It is rare for pesticides to be swallowed, especially by adults. However, accidents where ruptured hoses spray pesticide mixtures into the mouth have occurred. There have also been reports of people drinking from soft drink containers that contained pesticides. If it is suspected that a pesticide has been swallowed, read the label for first aid instructions. With some pesticides, labels recommend inducing vomiting. Others warn against inducing vomiting but recommend having the person drink water, milk, or solutions of activated charcoal or gelatin. Some pesticides are corrosive and may cause additional injury if vomiting is induced. Others may contain petroleum distillates that could enter the lungs and cause serious damage if vomiting occurs. If no label is available and the person is alert and able to swallow, have him or her drink plenty of water to dilute the ingested pesticide. Generally, an adult is given a quart of water to drink, and a child under age 7 is given a large glass. Never give liquids or induce vomiting to an unconscious or convulsing person. In all cases of swallowed pesticides, seek medical help immediately.

Skin. One of the most common types of exposure involves the skin. Spills, splashes, ruptured hoses, and drift all may cause skin exposure. Should someone get a pesticide onto his or her skin, get the person away from the contaminated area to avoid additional exposure. Remove contaminated clothing and wash the affected skin area with plenty of water and soap. If skin irritation or other pesticide symptoms appear, seek medical attention.

Eyes. The eyes are very vulnerable to splashes, sprays, drift, and fumes. Should any pesticide spray, dust, or fumes get into someone's eyes, take immediate action to reduce the chances of serious injury. Open the eyelid and irrigate the affected eye with a stream of clean, gently running water for at least 15 minutes. If running water is not available, slowly pour clean water from a glass, water cooler, or other container onto the bridge of nose, rather than directly into the eye. Seek medical attention immediately.

Lungs. Inhaled chemicals, such as pesticide dusts, vapors from spilled pesticides, and fumes from burning pesticides, can cause serious lung injury. Some pesticides can also be absorbed into the body through the lungs. The immediate first step is to get the person into an area where there is fresh air. Wear an appropriate respirator if you must enter any enclosed area to rescue someone who has been overcome by pesticide fumes.

If pesticide fumes overcome someone, follow these guidelines:

- Get the exposed person into fresh air.

- Loosen clothing to make breathing easier and release pesticide vapors trapped between clothing and skin.
- If breathing has stopped, but the victim has a pulse, administer mouth-to-mouth respiration (rescue breathing); if the victim has no pulse, give cardiopulmonary resuscitation (CPR) until help arrives.
- To reduce chances of the person going into shock, keep the person calm and lying down.
- Remove contaminated clothing and prevent chilling by wrapping the person in a blanket.
- Keep the air passages clear by making sure the head is tilted back.
- Get immediate medical care.

Medical attention must always be obtained for anyone suffering from pesticide inhalation because there may be delayed effects caused by damage to the lungs. Call for an ambulance or transport the person to the nearest medical facility. Remember to provide the medical care provider with information about the pesticide (from the label, if possible). Include the name of the pesticide and the manufacturer.

HEAT STRESS

Heat stress is the illness that occurs when the body builds up more heat than it can cope with. Heat stress is not caused by exposure to pesticides, but it may affect pesticide handlers who are working in hot conditions. Wearing personal protective equipment—clothing and devices that protect the body from contact with pesticides—can increase the risk of heat-related illness by limiting the body's ability to cool down.

Avoiding Heat Stress

Before beginning a pesticide-handling task, think about whether any of these factors are likely to contribute to heat stress:

- heat: temperature, humidity, air movement, and sunlight
- workload: the amount of effort a task takes
- personal protective equipment (PPE)
- drinking water intake
- scheduling

High temperatures, high humidity, and sunlight increase the likelihood of heat stress. Because hard work causes the body to increase its heat production, a person is more likely to develop heat stress when working on foot than when driving a vehicle. Lifting or carrying heavy containers or equipment also increases the likelihood of becoming overheated.

Signs and Symptoms of Heat Stress

Heat stress, even in mild forms, makes a person feel ill and reduces the ability to work efficiently. A person experiencing heat stress may get tired quickly, feel weak, be less alert, and his or her judgment may be impaired. Heat stroke, a severe form of heat stress, is a very serious illness. Unless the victim is cooled down quickly, he or she can die. Severe heat-related illness is fatal to more than 10% of its victims, even young, healthy adults. A person who has had a heat-related illness may remain sensitive and intolerant to heat for months and may be unable to return to the same type of work.

If you or a coworker experience any symptoms of heat stress take immediate action to cool down. Symptoms may include

- fatigue (exhaustion, muscle weakness)
- headache, nausea, and chills
- dizziness and fainting
- loss of coordination
- severe thirst and dry mouth
- altered behavior (confusion, slurred speech, a quarrelsome or irrational attitude)
- muscle or stomach cramping

Heat cramps can be painful. These

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FIGURE 5-5.

Calculate the size of the treatment area and carefully adjust and calibrate your application equipment so that you mix only the amount of pesticide needed for the job.

are muscle spasms in the legs, arms, or stomach caused by the loss of body salts through heavy sweating. To relieve cramps, drink cool water. Stretching or kneading the muscles may temporarily relieve the cramps.

First Aid for Heat Stress

It is not always easy to tell the difference between the symptoms of heat stress and pesticide poisoning, because the signs and symptoms are similar. If you are not sure, do not waste time trying to decide what is causing the illness, but get medical help right away. If the person is definitely suffering from heat-related illness, take the following first aid steps and then seek medical care:

- Get the victim into a shaded or cool area.
- Cool the victim as rapidly as possible by sponging or splashing the skin, especially around the face, neck, hands, and forearms, with cool water or, when possible, by immersing the victim in cool water.
- Carefully remove all PPE and any other clothing that may be making the victim hot.
- Have the victim, if conscious, drink as much cool water as possible.
- Keep the victim quiet.

Severe heat stress (heat stroke) is a medical emergency! Cool the victim immediately. Brain damage and death may result if treatment is delayed.

PESTICIDE IMPACTS ON THE ENVIRONMENT

Spills, leaks, and offsite drift of pesticides may result in environmental contamination. Some pesticide spills have the potential to seriously contaminate aquatic areas or groundwater aquifers. The following are steps you can take to avoid incidents that might lead to environmental contamination.

Mixing Pesticides. Calculate the size of the treatment area and carefully adjust and calibrate your application equipment so that you mix only the amount of pesticide needed for the job (Figure 5-5). While mixing, do not overfill the spray tank. Use an air gap on filling pipes to prevent backflow of the pesticide mixture into the water supply. Never leave a sprayer unattended while it is being filled.

Always triple-rinse empty containers and put the rinsate into the spray tank. Keep rinsed containers under your control or store them in a locked area until they can be recycled or taken to a designated disposal site.

Application Equipment. Before putting pesticides into the spray tank, check to ensure there are no cracked hoses or other leaks and that the filters, screens, and nozzles are clean. Replace or repair any defective or worn equipment.

Algae can not only clog filters and nozzles (Figure 5-6), but can react with some pesticides to reduce pesticide effectiveness. If the water you plan to use for filling the spray tank does not appear clean, do not use it. Pesticides may also react with certain chemicals in the water. For example, chlorine in domestic water supplies may combine with some pesticides to reduce effectiveness.


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FIGURE 5-6.

Algae and other contaminants in the water used for mixing a pesticide can clog filters and nozzles and react with some pesticides to reduce their effectiveness.

Thoroughly clean application equipment immediately after finishing your application. Rinse and clean the equipment at the application site. This will assure that pesticide residues in the rinsate remain with the pesticide that was just applied.

Application Techniques. Aquatic pesticide applications are made with several types of application equipment, including hand sprayers, dusters, powered hydraulic sprayers, and aircraft. Whatever equipment is used, many of the precautions to prevent environmental contamination are the same. These include:

- Read and follow the label. Applications that vary from label directions are violations of federal and state laws.
- Use the correct application equipment and make sure it is properly maintained and adjusted. Clean all screens, strainers, and nozzles and make sure they are functioning properly; use nozzles that are suitable for the application site; check all lines, valves, and seals for leaks.
- Calibrate your application equipment frequently. Follow the calibration guidelines in Chapter 6 of this manual.
- Check and recheck the weather forecast to be sure conditions will remain favorable for application and effectiveness of the pesticide.
- Avoid spraying near sensitive areas.
- Avoid overapplication. Do not make field adjustments to the sprayer in a recently sprayed area.
- Avoid draining leftover spray material onto the ground or into the water. Prevent having leftover pesticide mixtures by carefully calibrating the application equipment and accurately measuring the

size of the treatment area. If you cannot legally apply leftover spray material, send it to a hazardous waste disposal site.

The optimum conditions for spray applications are when the air is still, humidity is high, and any potential drift will be away from sensitive areas. Things you can do to reduce drift include lowering the spray pressure, keeping the boom height and nozzles properly adjusted, using large nozzle sizes to create larger, heavier droplets, and using drift-reducing additives if the label permits and if these additives are registered for use on the application site.

Protecting Nontarget Organisms. There are several ways to avoid injury to nontarget organisms, especially if you are applying insecticides. Select insecticides and insecticide formulations that are least toxic to nontarget organisms, and use the lowest rate that will still control the target pest. Whenever possible, use spot treatments that minimize the amount of insecticide you need to apply. The best way to protect honey bees and other nectar feeders is to avoid applications when plants in the treated area are blooming. Or, apply these sprays early in the morning, late in the afternoon, or during the night when the foraging insects are not present.

Avoiding Leaks and Spills. Leaks and spills are usually the result of faulty equipment or handler carelessness. Carefully plan in advance all aspects of handling pesticides to help avoid such problems. However, should they occur, treat all leaks and spills as emergencies. Leaks or spills can happen while transporting, mixing, applying, or storing pesticides.

If a pesticide spills onto a public roadway, contact the California Highway Patrol or the State of California Office of Emergency Services (or dial 9-1-1). On public roads, these agencies will take charge of coordinating cleanup and protecting the public. Report all leaks and spills, no matter where they occur, to your local county agricultural commissioner. Sidebar 14 contains a checklist for handling pesticide spills.

Handling Pesticide Fires. Pesticide fires require special care because smoke and fumes generated by burning pesticides may be toxic. If a pesticide fire occurs while you are in a boat, there is the added risk that the engine may catch on fire or that the gasoline tank may explode. Always read the label instructions and know what to do before an emergency occurs. For fires in enclosed areas, the area must be evacuated and isolated and the fire contained. Toxic fumes can hamper firefighting efforts, and water must be used with caution. High-pressure water can splash or spread the pesticide.

If a pesticide fire breaks out, call the fire department as quickly as possible (9-1-1), and inform them that it is a fire involving pesticides. Tell them which chemicals are involved. Immediately leave the area to avoid breathing toxic fumes and to prevent serious injury in case there is an explosion. Evacuate and isolate the area surrounding and downwind of the fire where fumes and toxic smoke may drift. Protect animals and move equipment that could be damaged by the fire or fumes or that could impair firefighting efforts. When firefighters arrive, provide them with the Material Safety Data Sheets for the pesticides involved in the fire.

Disposing of Empty Containers and Unused Pesticides. Be sure to dispose of your empty containers or leftover pesticides properly. Never bury containers or the pesticide product, and do not put them into trash dumpsters. Do not dump pesticides or pesticide mixtures onto the soil or into sewers, drains, septic systems, or bodies of water. Unused pesticides and pesticide mixtures that cannot be applied to a legal site must be taken to a hazardous waste disposal facility. Send triple-rinsed pesticide containers to a landfill or pesticide container recycling facility.

SIDEBAR 14

Handling Pesticide Spills

Certain practices should be followed with all pesticide spills. If it is a major spill, seek the help of professionals to minimize damage to human health and the environment. Get advice on cleaning up spills from CHEMTREC at (800) 424-9300.

When a spill occurs, take the following steps:

☐ Clear and secure the area. Barricade or rope off the contaminated area, evacuate people, and keep people and animals away.

☐ Provide first aid for anyone injured or exposed. Move the victims to fresh air. Seek medical help if necessary.

☐ Ventilate enclosed areas. If this is an indoor spill, such as a spill that occurs while you are mixing chemicals, open the doors and windows. Ban smoking or anything heat-generating, because some pesticides are flammable. Turn off electrical appliances and motors.

☐ Contact the proper authorities. Depending on the jurisdiction, these authorities could include the highway patrol, county sheriff, city police, or local fire department. Always notify your county agricultural commissioner.

☐ Before beginning any cleanup, put on the label-prescribed personal protective equipment. If you are uncertain what the pesticide is, wear the maximum personal protective equipment.

☐ Contain the leak. If the spill is due to a leaking container, stop the leak and transfer the pesticide to another container or patch the leaking container. Use strong tape to repair paper bags and cardboard boxes.

☐ Clean up the pesticide. If it is a liquid on a solid surface such as concrete or asphalt, use soil, sand, sawdust, cat litter, or absorbent clay to form a containment dam around the liquid. Brush absorbent material toward the center of the spill. Add additional absorbent material if necessary.

☐ Clean nonporous surfaces, safety equipment, and cleanup equipment. Always read the MSDS for information on what type of solution to use to clean up the contaminated surfaces.

☐ Follow the laws regarding proper disposal of pesticide waste. Check with your local county agricultural commissioner or your Regional Water Quality Control Board. Place the saturated absorbent material or spilled dry product and any contaminated soil in a disposable container. Label the container with the pesticide name and signal word.

REVIEW QUESTIONS

(answers on page 145)

1. Which of the following types of information is *not* found on the pesticide label?
- ☐ a. Personal protective equipment requirements for handlers
- ☐ b. Specific precautions handlers must follow
- ☐ c. First aid measures in case of exposure
- ☐ d. Phone numbers of Regional Poison Control Centers

2. The letters "AS" in a pesticide product brand name indicate that the formulation is an:
- ☐ a. Aqua solvate
- ☐ b. Aqueous suspension
- ☐ c. Aquaculture solvent
- ☐ d. Aquatic solution

3. The letter "F" in a pesticide product brand name indicates that the product is formulated as a:
- ☐ a. Finely-ground powder
- ☐ b. Flowable liquid suspension
- ☐ c. Friable dust
- ☐ d. Fluid

4. The inert or nonpesticidal ingredients of a pesticide formulation are:
- ☐ a. Always listed by name on the pesticide label
- ☐ b. Listed on the pesticide label as a percentage, by weight, of the total contents
- ☐ c. The ingredients that directly affect the target pests
- ☐ d. Materials you must add to the spray tank before adding the pesticide

5. What significance does the EPA Registration Number on a pesticide label have?
- ☐ a. It is unique to that pesticide product
- ☐ b. You use this number to determine if the pesticide product is classified as *general-use* or *restricted-use*
- ☐ c. It is the code that tells where the product was manufactured or packaged
- ☐ d. The number indicates the degree of hazard associated with the product

6. The *signal word* on a pesticide label reflects the:
- ☐ a. Relative hazard of the formulated product
- ☐ b. Major uses of the pesticide
- ☐ c. Safety of the product to the plants that get sprayed
- ☐ d. Hazard to people entering a treated area after the restricted-entry interval expires

7. The *signal word* that indicates the most hazardous formulation is:
- ☐ a. *Caution*
- ☐ b. *Warning*
- ☐ c. *Danger*
- ☐ d. *Poison*

8. Ocular exposure refers to pesticides getting into or onto the:
- ☐ a. Mouth
- ☐ b. Nose
- ☐ c. Skin
- ☐ d. Eyes

9. Dermal exposure refers to pesticides that contact the:
- ☐ a. Nose
- ☐ b. Skin
- ☐ c. Eyes
- ☐ d. Mouth

10. The signal word *Danger*, accompanied by the word *Poison* and a skull and crossbones, means that the pesticide is:
- ☐ a. More effective in controlling the target pest than other types of pesticides
- ☐ b. Highly toxic to people
- ☐ c. Less toxic to people than pesticides having just the signal word *Danger*
- ☐ d. Less effective in controlling aquatic weeds

11. Any use of a pesticide that is inconsistent with its labeling, other than lower rates and less frequent applications, is:
- ☐ a. Illegal, unless it is approved by the agricultural commissioner
- ☐ b. Allowable as long as the specified personal protective equipment is used
- ☐ c. Allowable as long as you do not exceed twice the label-recommended rate and the material is applied to a listed site
- ☐ d. Always illegal

12. The "directions for use" section of the label is:
- ☐ a. The suggested ways to possibly use the pesticide
- ☐ b. Precautionary information that you should follow
- ☐ c. The legal way the pesticide must be used
- ☐ d. Information provided for people who use the treated area after an application is made

13. Most reported pesticide illnesses or injuries are the result of:

- ☐ a. Purchasing the wrong pesticide for the target pest
- ☐ b. Improper disposal of empty containers and leftover spray material
- ☐ c. Failure to wear the label-prescribed personal protective equipment
- ☐ d. Storing pesticides in the wrong place

14. The part of the body most commonly exposed to pesticides is the:

- ☐ a. Skin
- ☐ b. Mouth
- ☐ c. Lungs
- ☐ d. Eyes

15. The *toxicity* of a pesticide refers to:

- ☐ a. Its effectiveness in controlling the target pest
- ☐ b. The way a person may be exposed to it
- ☐ c. Its capacity to cause harm
- ☐ d. Its impact on the environment

16. If someone gets a pesticide on his or her skin, the person should:

- ☐ a. Remain calm and stop working for the rest of the day
- ☐ b. Immediately wash the affected area with plenty of soap and water
- ☐ c. Drink large quantities of fluids for the next 24 hours
- ☐ d. Report the incident to their supervisor immediately upon completion of the work shift

17. Where is the best place to clean pesticide application equipment?

- ☐ a. At the mixing and loading site
- ☐ b. Inside the equipment storage shed
- ☐ c. At the application site
- ☐ d. Near the pesticide storage area

18. What should you do with empty pesticide containers?

- ☐ a. Bury them, preferably near the application site
- ☐ b. Discard them into the body of water being treated
- ☐ c. Triple-rinse and store them for other uses
- ☐ d. Triple-rinse and dispose of them at a landfill or offer them for pesticide container recycling

6 Selecting and Calibrating Aquatic Herbicide Application Equipment

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It is important to apply the correct amount of herbicide to the aquatic areas you are treating.

Aquatic herbicides are applied in several ways—primarily by motorboat, airboat, fixed-wing aircraft, and helicopter (Figure 6-1). Boat applications use bow- or stern-mounted injectors, sprayers, centrifugal spreaders, and blower-type spreaders. Usually this equipment can be removed or interchanged with other types of application equipment, including hand-held spray guns (Figure 6-2). In addition to being applied from boats and aircraft, aquatic herbicides are also applied from shore using high-pressure, powered equipment and lightweight portable sprayers.

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FIGURE 6-2.

Hand-held spray guns are useful accessories to boat-mounted sprayers. They are used for spot treatments to control emersed and shoreline weeds.

TYPES OF EQUIPMENT

Some of the equipment used to apply liquid and granular herbicides in aquatic environments is similar to that used in agricultural and large landscape applications. For example, typical aquatic weed spraying equipment includes a tank in which the herbicide is diluted with water before application, an engine-powered pump, agitators inside the tank, a pressure gauge and pressure regulator, control valves, and filters or strainers. This type of sprayer is suitable for applying herbicides to emersed, free-floating, and rooted floating weeds in large ponds, reservoirs, and lakes. More

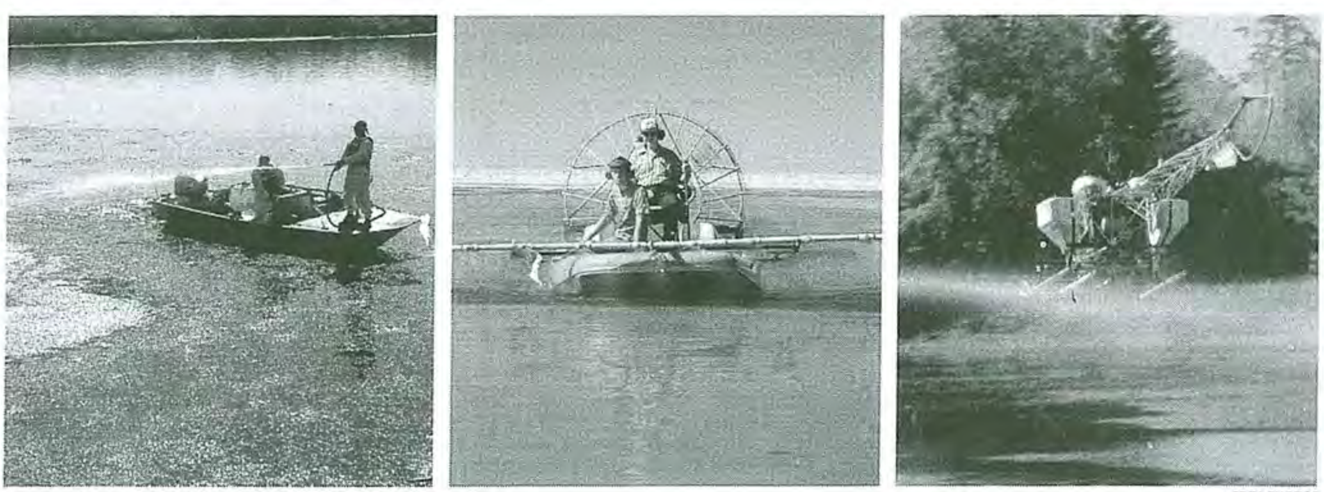

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FIGURE 6-1.

Inboard or outboard motorboats, airboats, and helicopters are used to apply aquatic herbicides.

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FIGURE 6-3.

Nozzle injection equipment eliminates measuring, mixing, and frequent tank refilling.

sophisticated spraying equipment meters and injects concentrated herbicide directly into the nozzles, where it is properly diluted with water as it is being sprayed. These computer-controlled devices are practical when treating especially large areas because they eliminate measuring, mixing, and frequent tank refilling (Figure 6-3).

Certain aquatic weed applications require the use of specially designed equipment in order to control submersed weeds or to place herbicides into the rooting area of lakes and ponds. Other types of specialized equipment are also used for treating flowing water.

Herbicides to control aquatic weeds are applied as surface sprays, subsurface applications, and bottom applications (Figure 6-4). In addition, granules are broadcast over the water's

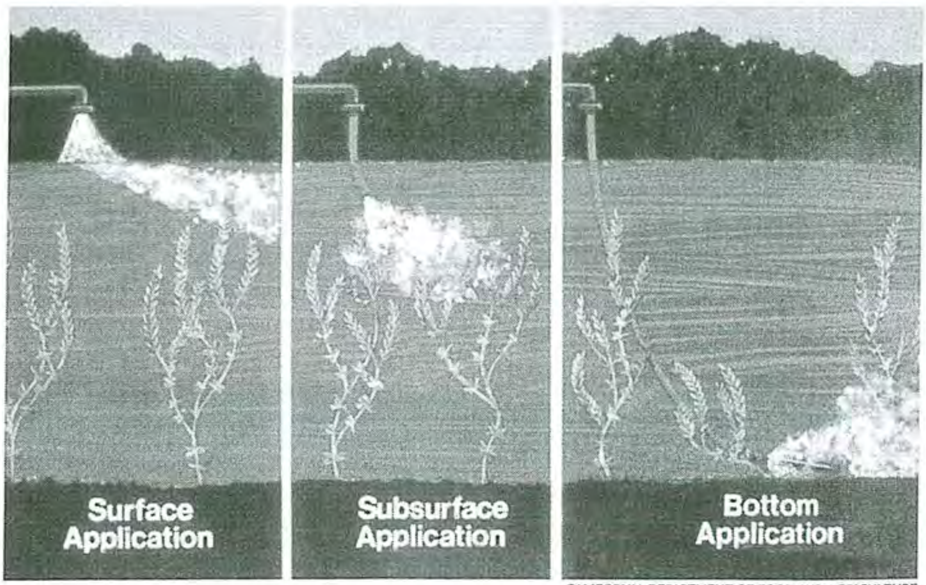

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FIGURE 6-4.

Aquatic herbicides are applied to the water's surface, subsurface, and bottom.

FIGURE 6-5. JACK KELLY CLARK

Surface sprays are used to control weeds that have leaves extending above the water.

surface and then fall through the water to the bottom. Applications to flowing water are applied to the surface or subsurface.

Surface Spray Applications

Weeds with leaves that extend above the water (emersed, free-floating, and rooted floating) are typically treated with herbicide surface sprays (Figure 6-5). Shoreline weeds are also sprayed with liquid herbicide mixtures. Hand-held, vehicle-mounted, boat-mounted, and aerial sprayers are used, depending on the amount of area to be treated and its accessibility.

Powered liquid application equipment is suitable for treating large areas and shorelines. Equipment designed for spraying small areas and for making spot treatments includes compressed air and backpack sprayers.

Compressed Air Sprayers. Compressed air sprayers are easy to use and work well in a variety of settings. A sprayer of this type has a spray wand with a nozzle or small boom at its tip. Compressed air sprayers usually have plastic tanks that hold from ½ gallon to 5 gallons of pesticide mixture. They have hand-operated pumps to compress the air inside the tank, creating the spray pressure.

Backpack Sprayers. Backpack sprayers provide a simple solution to treating smaller shoreline areas that are difficult to reach with boat-mounted equipment (Figure 6-6). They are relatively inexpensive, simple to operate, and easy to clean and store. Backpack sprayers can be equipped with a single-nozzle wand for spot treatments or a small boom for narrow swath treatments.

Backpack sprayers typically have plastic tanks with capacities ranging between 3 and 5 gallons. Most backpack sprayers are pumped continuously by hand while pesticide is being applied. Some use a source of compressed air or carbon dioxide to pressurize the tank. Backpack units deliver between 0.1 and 2 gallons per minute (gpm) at pressures up to 100 psi. Small gasoline engines power some backpack sprayers. The engine drives the pump, eliminating the need for hand pumping, and provides higher and more even pressure.

Nozzles. Manufacturers develop pesticide spray nozzles for practically every kind of application. Nozzles can be used singly on hand-held wands or as multiples on small hand-held booms. On powered equipment, many

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FIGURE 6-6.
Backpack sprayers are used to treat areas that are inaccessible to larger, powered equipment.

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FIGURE 6-7.
On powered equipment, many nozzles can be positioned along a boom or on a manifold.

nozzles are positioned along booms or manifolds (Figure 6-7). Selecting the right nozzle for spraying equipment is important because the nozzle determines the spray pattern, angle, droplet size, and flow rate. Nozzles also control how thoroughly the target is covered with spray.

Different nozzle sizes produce droplets ranging from very fine to very coarse. Nozzles that produce fine droplets are usually recommended for postemergent applications that require thorough leaf coverage; however, fine droplets are most prone to drift. Nozzles that produce medium-sized droplets are commonly used for contact and systemic herbicides. These also can be used for preemergent surface-applied herbicides, such as along stream banks and canals. Nozzles that produce coarse droplets are used when weather conditions increase problems of drift.

Nozzles produce different droplet sizes at different pressures. For example, a nozzle that produces medium or coarse droplets at low pressures generates an increasing number of fine droplets as the spray pressure increases. These smaller droplets increase the potential for drift, which poses both environmental and safety concerns. Preventing drift often means the difference between a proper application and an illegal application plagued with safety hazards.

The Safe and Effective Use of Pesticides, Second Edition includes a section to assist you in selecting appropriate nozzles for your aquatic applications. Also, catalogs from nozzle manufacturers have specific and detailed information on the uses and limitations of different types of nozzles.

Flowing Water Applications

Flowing water applications present special problems because the moving water disperses and dilutes the herbicide as the herbicide moves downstream. When making this type of application, you must make careful calculations of the size of the area to be treated and the volume and flow rate of the water. Concentrated herbicides are applied to flowing water as a slug, or they are metered into the water over time.

Slug Applications. A single measured dose of herbicide dumped into moving water at an upstream location is known as a slug. The concentration of this slug gradually decreases as it is diluted with water while moving downstream. At a certain point downstream, the concentration becomes so diluted that the herbicide is ineffective.

Metered Flow Applications. Metering devices can be placed upstream to slowly drip measured amounts of herbicide into the flowing water. This provides a more even concentration of herbicide throughout the treatment area. Metered flow applications require careful calculation of the volume and flow rate of the moving water (see page 132).

Bottom Applications

Surface sprays cannot be used to control submersed weeds or to apply herbicides that are taken up by plant roots. Instead, the herbicides must be injected into the water near the bottom. To do this, weighted brass pipes bored with small holes are used (Figure 6-8). These pipes are connected by hoses to a boom on the boat.

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FIGURE 6-8.

Subsurface treatment for controlling submersed weeds includes specialized equipment such as these weighted brass pipes bored with small holes.

FIGURE 6-9. CDFA PHOTO

Granular herbicides are commonly applied with bow-mounted centrifugal spreaders.

The herbicide mixture is pumped through the hoses and exits through small holes in the pipes as the pipes are being dragged along near the bottom of the lake or pond.

Bottom applications to control submersed weeds are usually applied early in the growing season (spring) when the vegetation is still small.

Granular Applications

Granular herbicide formulations are used to control large submersed weeds such as egeria and coontail. The granules, usually formulated with clay, sink to the bottom before the active ingredient is released.

Granular herbicides are commonly applied with bow-mounted centrifugal or blower-type spreaders (Figure 6-9). Usually, granules should not be scattered across the water surface by hand because of the difficulty in obtaining even distribution.

Centrifugal and blower-type spreaders are both used for aquatic weed control, and each type has advantages. Centrifugal spreaders can treat swaths as wide as 30 to 40 feet when relatively large granules are applied. Blower-type spreaders create less dust than centrifugal spreaders, because there is less pellet damage during application.

Servicing and Maintaining Pesticide Application Equipment

To do a good job of applying any pesticide you must have equipment that operates properly. Regular servicing and maintenance keeps your equipment in good shape (Figure 6-10). To service and maintain your aquatic application equipment, refer to your owner's instruction manual. Study it thoroughly and keep it for future reference.

For sprayers, the most costly maintenance problems are pump and nozzle wear caused by abrasive particles either in the spray material or water, and sprayer deterioration from chemical corrosive action. These problems can be kept to a minimum by

- using clean water for the spray mixture
- selecting less-abrasive formulations whenever possible
- keeping the proper strainers and filters in place at all times
- ensuring that there is always liquid in the tank before operating the pump

- ensuring that no sediment or suspended organic matter is drawn into the system when you are pumping lake water as a diluent
- thoroughly cleaning the pumping system after each use to reduce corrosion
- following the equipment manufacturer's maintenance guidelines and the instructions for storing the sprayer at the end of the season

CALIBRATING EQUIPMENT

The term *calibration* refers to all the adjustments you make to your equipment to be sure you apply the correct amount of herbicide to the aquatic area you are treating. Failure to calibrate equipment properly may result in an ineffective herbicide application and carries the potential for excessive or illegal residues remaining in the treated waters. General calibration principles are covered in *The Safe and Effective Use of Pesticides, Second Edition*. Read those guidelines and the equipment manufacturer's instruction manual before beginning to calibrate your equipment.

The following section discusses the steps you need to take to calibrate some aquatic herbicide application equipment. However, it does not cover common calibration shortcuts and quick calculations. These shortcuts are applicable only in specific situations or for certain types of application equipment. Formulas for these handy techniques may be available in equipment manuals or trade journals. Learn the principles of proper calibration first. Then, if appropriate, adopt one of these quick calibration methods if it applies to your equipment and special needs.

Numerous factors affect the application rate of herbicides in an aquatic environment, so you may need to calibrate your equipment before each application. You also may need to make adjustments during an application to compensate for changes in the application area or changes in weather conditions. Factors that affect the rate of application include

- boat speed
- total area being treated
- width of the area to which the herbicide can be applied with a spray boom, hand-held spray gun, spreader, or trailing hoses as the boat moves forward
- pump output
- the rate at which water is drawn from a lake or pond to dilute and propel the herbicide

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FIGURE 6-10.

Regular servicing and maintenance keeps your pesticide application equipment in good shape. Follow the servicing recommendations found in the owner's manual provided by the equipment manufacturer.

FIGURE 6-11. JACK KELLY CLARK

Equipment calibration is needed to assure that the correct amount of herbicide is applied to control target weeds.

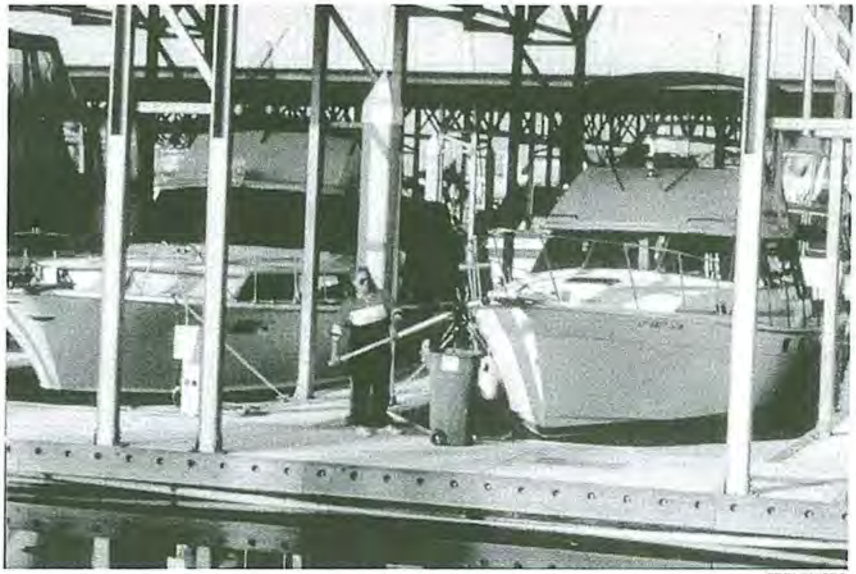
Why Calibration Is Essential

The main reason for calibrating aquatic application equipment is to determine how much liquid herbicide to put into the spray tank or how much granular herbicide to put into the spreader hopper. This assures that the correct amount of chemical is applied. Accurate calibration is necessary for

- effective pest control
- protecting human health, the environment, and treated waters
- preventing waste of resources
- complying with the law

Effective Pest Control. Manufacturers of herbicides spend a considerable amount of money researching ways to use their products. Their research includes determining the correct amount of herbicide to apply in order to effectively control target weeds. Using less than the labeled amount of herbicide may result in inadequate control and waste valuable time and money (Figure 6-11). Using more than the label rate is illegal.

Human Health and Environmental Concerns. If you apply herbicides at higher than label rates, you could endanger the health of people using the aquatic area (Figure 6-12). Poorly calibrated application equipment may also expose equipment operators to concentrations of herbicide for which they are not adequately protected. Improper herbicide concentrations may cause injury to the environment. Calibrating equipment to maintain application rates within label requirements helps to protect the environment.



CDFA PHOTO

FIGURE 6-12.

Improperly applying pesticides in aquatic areas could endanger the health of people who use these areas.

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FIGURE 6-13.

Always read the herbicide label to find the application rate for the site and weeds you are treating.

Preventing Waste of Resources. Using the improper amount of herbicide wastes time and adds unnecessary costs. Not only are herbicides expensive, but the fuel, labor, and equipment wear and tear required to make extra applications are costly, too.

Complying with the Law. People who use herbicides improperly are subject to criminal and civil charges, resulting in fines, imprisonment, and lawsuits. Anyone who applies pesticides is liable for injuries or damage caused by improper applications.

Calibration Methods for Liquid Application Equipment

To calibrate your equipment you must first determine the amount of herbicide to apply—the application rate. *Check the herbicide label for this information* (Figure 6-13). Best results are usually obtained by carefully following label recommendations. Under no circumstances can you exceed maximum label rates. Herbicide labels may prescribe applications as:

Amount per Acre. This method applies a measured amount of dry- or liquid-formulated material per acre of surface water or bottom soil. It is the most common type of aquatic application. The label lists the application rate as a given quantity per acre, such as pounds, dry ounces, fluid ounces, pints, quarts, or gallons.

Metered-Flow Applications. For flowing water, this is the rate that an herbicide is continuously applied for a period of time at an upstream location.

Parts-per-Million Dilutions. The label may base application rates on a desired concentration, in parts-per-million (ppm), of the active ingredient in the treated water.

Percentage Solutions. When spraying emerged foliage or shore plants, the label may direct you to mix a percentage solution of herbicide formulation in the spray tank.

Calibration methods vary depending on which of the above types of application you are making. The following sections discuss these various methods. You need a few simple tools to calibrate aquatic herbicide application equipment (Sidebar 15). Put these items in a small toolbox and use them only for calibration purposes. Keep your tools clean and in good working condition. *Make equipment calibration a professional operation* (Figure 6-14).

Amount per Acre—Liquid Applications

The label calls for a given amount of herbicide per acre. Calibrating the sprayer allows you to determine how much area each spray tank will cover when the equipment moves at a known speed and operates at a known pressure. To accomplish this calibration you need to measure these four factors:

SIDEBAR 15

Tools Needed for Calibration

1. **Stopwatch.** A stopwatch is essential for timing travel speed and flow rates. Never rely on a wristwatch unless it has a stopwatch function.

2. **Measuring tape.** A 100-foot moisture- and stretch-resistant measuring tape is needed for marking off the distance to be traveled and for measuring spray swath width.

3. **Calibrated liquid container.** A container with a capacity of 1 or 2 quarts, calibrated for liquid ounces, is needed for measuring spray nozzle output.

4. **Scale.** A small scale, capable of measuring pounds and ounces, is used for weighing granules collected from a granule applicator. The most accurate weight measurements can be obtained from scales having maximum capacities between 5 and 10 pounds.

5. **Pocket calculator.** A pocket calculator is needed for making calculations in the field.

6. **Pressure gauge.** An accurate, calibrated pressure gauge, with fittings compatible with spray nozzle fittings, is helpful for checking boom pressure and for calibrating the sprayer pressure gauge.

7. **Flow meter.** A flow meter attached to a flexible hose or filling pipe can be used for measuring the amount of water put into a tank. This can be helpful in measuring tank capacity and in determining the amount of liquid used during a calibration run. Both mechanical and electronic flow meters are available. If these are not available, a calibrated 5-gallon pail can be used instead.

8. **Flagging tape.** Colored plastic flagging tape is useful for marking off measured distances when determining applicator speed.

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FIGURE 6-14.

A few simple tools, kept in a special toolbox, help make calibration more accurate and easy to do. Items shown here include measuring tape, flagging tape, stopwatch, pressure gauge, calculator, flow meter, calibrated containers, and a scale.

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FIGURE 6-15.

While measuring the volume of a spray tank, calibrate the tank's sight gauge.

- tank capacity
- travel speed
- flow rate
- spray swath width

Tank Capacity. You always need to know exactly how much liquid the spray tank holds. Physically measure the capacity of the spray tank (or tanks if the equipment has more than one). Never rely on manufacturers' tank size ratings, because these may be approximate volumes or they may not take into account fittings installed inside the tank. Also, the capacity of spray lines, pump, and filters influences tank volume.

Perform this operation when the water is calm or when the equipment is on a level land surface. Be sure the tank is completely empty, and then close all valves to prevent water leaks. Add measured amounts of clean water until you completely fill the tank. Use a flow meter attached to a hose, bucket, or other container of known volume. A 5-gallon bucket works well for small tanks. However, be sure to calibrate and mark the bucket before using it to fill the tank. If you are not using a flow meter, use smaller-volume calibrated containers to top off the tank. Record the total volume of water you put into the tank. Paint or engrave this figure onto the outside of the tank for permanent reference.

While filling the tank, calibrate the tank's sight gauge (Figure 6-15). Make marks on the tank or gauge as you put in measured volumes of water. If the unit does not have a sight gauge, mark volume increments on a dipstick. Then, always keep this dipstick with the tank. Use 1-gallon marks for tanks with a capacity of 10 gallons or less. Use increments of 5 or 10 gallons for tanks having a total capacity of 50 gallons or less. On larger tanks, use increments of 10 to 20 gallons. Once you calibrate the sight gauge or dipstick you can measure how much liquid is in the tank when it is not entirely full. Always take these readings on calm water or a level land surface.

Travel Speed for Water Craft. Always measure travel speed under actual application conditions. Because of changes in weather and water currents, it may be necessary to measure travel speed frequently.

Begin by measuring off a convenient distance. Use buoys or flags to mark each end of the course. Set the boat throttle to the speed that is suitable for the application (a tachometer is useful for monitoring engine speed). Bring the boat up to speed before crossing the first marker. Start a stopwatch as you cross the first marker and stop it when you pass the end marker. Record the time it took, in minutes, to travel this distance. Take this measurement in two directions and average the two times to allow for differences caused by wind or current. After finding the average time, in minutes, divide this into the length of the test run. See Sidebar 16 for an example of measuring the speed of a watercraft.

SIDEBAR 16

Calculating the Travel Speed of Water Craft or Ground-Operated Application Equipment

Measure travel speed under actual working conditions. For example, if making an application by boat, fill the tanks with water. Measure off any convenient distance using buoys or flags to mark each end of the course. Set the boat throttle to a speed that is suitable for the application. Use a stopwatch to time how long it takes to traverse the course in one direction. Then time how long it takes to travel the course again in the opposite direction. Average these times to accommodate for wind and current influences. Figure your travel speed using the following formulas.

1. Convert minutes and seconds into minutes by dividing the seconds (and any fraction of a second) by 60.

■ EXAMPLE

Your trip took 1 min and 47.5 sec.
47.5 sec ÷ 60 sec/min = 0.79 min

Add these amounts together:
1 min + 0.79 min = 1.79 min

2. Find the average run time by adding the *converted* minutes from each run and dividing by the number of runs.

■ EXAMPLE

Three runs were made
Run #1 = 1 min, 47.5 sec = 1.79 min
Run #2 = 1 min, 39.8 sec = 1.66 min
Run #3 = 1 min, 52.0 sec = 1.87 min
Total = 5.32 min

5.32 min ÷ 3 runs = 1.77 min/run average time

3. Find the number of feet traveled in 1 minute by dividing the measured distance by the average time.

■ EXAMPLE

The measured distance is 227 feet.
227 ft ÷ 1.77 min = 128.25 ft/min

4. If you wish to determine the speed in miles per hour, divide the feet-per-minute figure by 88 (the number of feet traveled in 1 minute at 1 mile per hour).

■ EXAMPLE

128.25 ft/min ÷ 88 ft/min/mi/hr = 1.46 mi/hr

Travel Speed for Applications on Land. Follow the guidelines in *The Safe and Effective Use of Pesticides, Second Edition* for measuring travel speed for hand-operated, towed, and self-propelled equipment operated on land.

Flow Rate. Measure the actual output of the sprayer when nozzles or emitters are new. Then measure it periodically thereafter to accommodate for wear. Manufacturers provide charts showing the output of given nozzle sizes at specified sprayer pressures. However, check the output under actual conditions of operation (Figure 6-16). Manufacturers' charts are most accurate when using new nozzles. Used nozzles may have different output rates because of wear, and even new nozzles may have slight variations in actual output. In addition, sprayer pressure gauges may not be accurate, which adds further error to the output estimate determined from charts.

Measure liquid sprayer output in gallons per minute. Select from one of the two methods described in the

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FIGURE 6-16.

Check the output of nozzles under actual operating conditions.

following sections, depending on the type of sprayer you are calibrating. The first method works for low-pressure sprayers and small hand-held units. It involves collecting a volume of water emitted out of individual nozzles over a measured time. The second method, for high-pressure sprayers, measures *output* of the sprayer over a known period.

Collection Method for Low-Pressure and Small Hand-Held Sprayers. Calibrate low-pressure sprayers by measuring the amount of spray emitted from each nozzle. These include low-pressure boom sprayers and backpack sprayers. If the sprayer has more than one nozzle, collect liquid from each separately. This allows you to compare each nozzle's output and points out any malfunction or wear. You need a stopwatch and a calibrated container for making measurements. Wear rubber gloves to avoid skin contact with the liquid. Stand upwind from the nozzles to prevent fine mist or spray from contacting your face and clothing. Wear eye protection to prevent spray droplets from getting into your eyes.

Fill the tank at least half full with water. Start the sprayer and bring the system up to normal operating pressure. Operate hydraulic agitators if they will be used during the application. This is important because hydraulic agitators divert some liquid from the nozzles and often lower the pressure in the system. Most power sprayers have a limited operating pressure range depending on the type of pump and power unit. Never attempt to operate equipment beyond its normal working range, because this may damage the pump. Adjust the pressure to the requirements of the spray situation and the nozzle manufacturer's recommendations. Check the pressure by attaching a calibrated pressure gauge at either end of the boom, replacing one of the nozzles. Open the valves to all nozzles and note the pressure, make adjustments as necessary, then remove the gauge and replace the nozzle.

SIDEBAR 17

Recording Nozzle Output

NOZZLE #	VOLUME (fl oz)	TIME (sec)
1	12.5 fl oz	23.2 sec
2	12.0	22.5
3	15.5	24.8
4	14.5	26.1
5	19.0	27.2
6	13.0	23.9

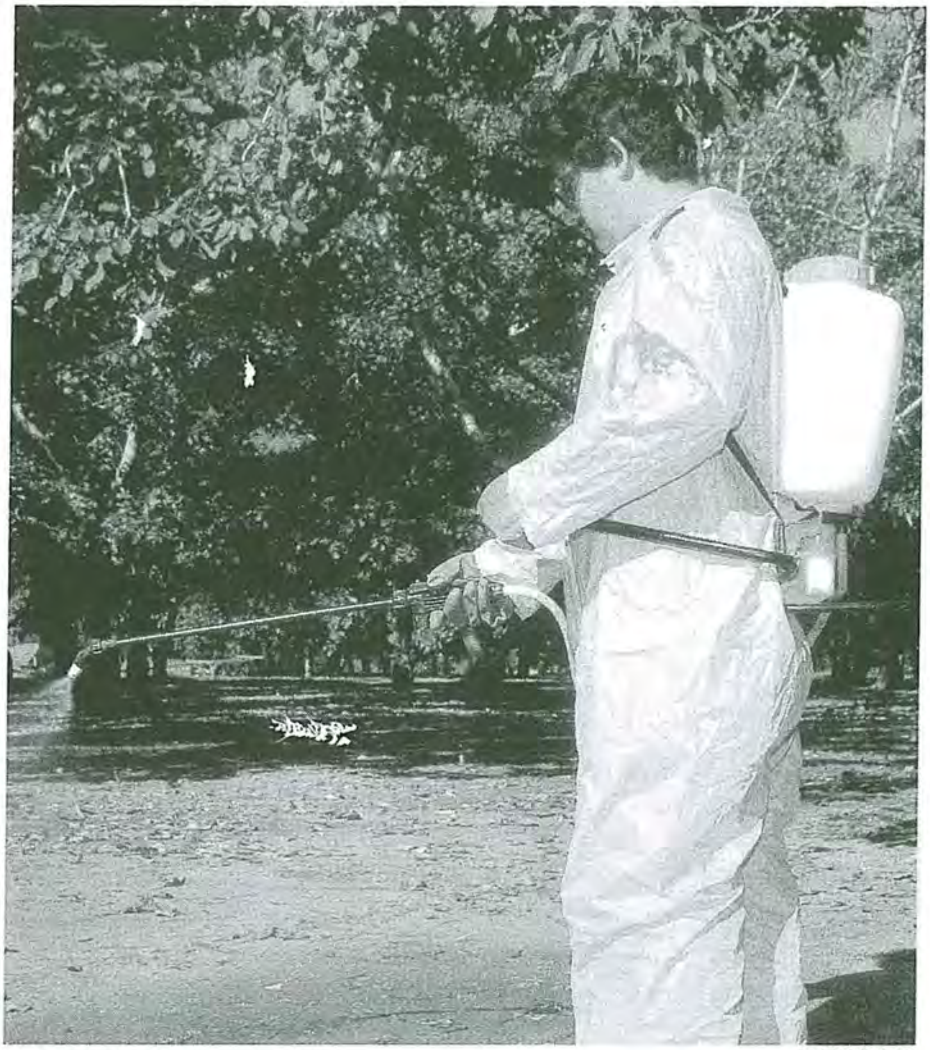

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FIGURE 6-17.

When calibrating backpack sprayers, collect the output from each nozzle while pumping the sprayer to maintain an even pressure.

While all nozzles are operating at the proper pressure, collect about 15 to 30 fluid ounces of liquid from each. Use a stopwatch to determine the time in seconds that elapsed while collecting each volume.

When calibrating backpack sprayers, pump the unit as you would during an actual application (Figure 6-17). Collect spray into a calibrated container for a measured time. Compressed air sprayers lose pressure during operation, so you must frequently pump them up. To calibrate, fill the tank about half full with water—this provides a sufficient volume of air to keep the pressure more uniform.

Record the volume of liquid collected from each nozzle or emitter and the time in seconds it takes to collect each amount. Use a format similar to Sidebar 17. Determine the output in fluid ounces per second for each nozzle by dividing the volume by the seconds that elapsed collecting it. Convert ounces per second into gallons per minute by multiplying the result by the constant 0.4688. This constant represents 60 seconds per minute divided by 128 fluid ounces per gallon.

Output among nozzles will usually vary. In the example in Sidebar 18, part 1, the output ranges from 0.250 gallons per minute to 0.328 gallons per minute. Assume that the rated capacity

SIDEBAR 18

Calculating Output Rate of Low-Pressure Sprayers

The following is an example of how to calculate the output of a sprayer that has 6 nozzles on a boom. It also shows how to compare the output from each nozzle to point out faulty nozzles. Use a calibrated container and a stopwatch. Collect fluid into the calibrated container from each nozzle separately. Use the stopwatch to measure the amount of time for each collection and record your results. Use the following steps to calculate the output rate.

1. Determine the output of each nozzle in gallons per minute by dividing the fluid ounces collected from each nozzle by the time required (in seconds) to collect it and multiplying the result by 0.4688 (60 seconds per minute divided by 128 fluid ounces per gallon).

EXAMPLE

Nozzle	fl oz ÷ sec			×	0.4688	=	gpm
1	12.5 ÷ 23.2	=	0.539	×	0.4688	=	0.253
2	12.0 ÷ 22.5	=	0.533	×	0.4688	=	0.250
3	15.5 ÷ 24.8	=	0.625	×	0.4688	=	0.293
4	14.5 ÷ 26.1	=	0.556	×	0.4688	=	0.261
5	19.0 ÷ 27.2	=	0.699	×	0.4688	=	0.328
6	13.0 ÷ 23.9	=	0.544	×	0.4688	=	0.255
					Total Output	=	1.640 gpm

2. Compute the percentage variation from the rated nozzle output. Divide the actual gallons-per-minute output by the rated output. Subtract 1 from this number and multiply by 100.

EXAMPLE

Nozzle	Actual gpm ÷ Rated gpm			Subtract 1.00			Multiply by 100	=	Percent variation
1	0.253 ÷ 0.250	=	1.012	−1.00	=	0.012	× 100	=	1.2
2	0.250 ÷ 0.250	=	1.00	−1.00	=	0.000	× 100	=	0.0
3	0.293 ÷ 0.250	=	1.172	−1.00	=	0.172	× 100	=	17.2
4	0.261 ÷ 0.250	=	1.044	−1.00	=	0.044	× 100	=	4.4
5	0.328 ÷ 0.250	=	1.312	−1.00	=	0.312	× 100	=	31.2
6	0.255 ÷ 0.250	=	1.020	−1.00	=	0.020	× 100	=	2.0

(as given by the manufacturer) for these nozzles at the recommended operating pressure is 0.250 gallons per minute. The variation among nozzles should not be greater than 5%, and the output of any nozzle should not exceed the manufacturer's rated output by more than 10%. Figure the percentage of variation, using the example in Sidebar 18, part 2. Divide the actual output by the rated output. Subtract 1.00 from this figure, then multiply by 100 to obtain the percentage of variation. Nozzles 3 and 5 in this example exceed these amounts and therefore must be replaced. However, whenever you replace any nozzles, recheck the flow rate of all the nozzles. Changing one nozzle may affect the pressure in the whole system. After changing nozzles, readjust the pressure regulator to maintain the desired pressure. Sidebar 19 shows how to recalculate the output in gallons per minute after replacing worn nozzles.

Measured Release Method for High-Pressure Sprayers. Due to the high pressures of larger sprayers, you cannot collect the spray from individual

SIDEBAR 19

Recalculating Output After Replacing Worn Nozzles

In this example, worn nozzles were replaced and the output from all the nozzles was remeasured. Part 1 below shows the new output calculations. Part 2 shows that all nozzles are within 5% of their rated capacities

1. Replace worn nozzles (numbers 3 and 5 in the example from Sidebar 18) and remeasure the output of all nozzles on the boom. Recalculate the output in gallons per minute for each nozzle. Add these rates together to determine the total output of the sprayer.

EXAMPLE

Nozzle	fl oz ÷ sec			×	0.4688	=	gpm
1	12.5 ÷ 23.2	=	0.539	×	0.4688	=	0.253
2	12.0 ÷ 22.5	=	0.533	×	0.4688	=	0.250
3	13.3 ÷ 24.5	=	0.542	×	0.4688	=	0.254
4	14.5 ÷ 26.1	=	0.556	×	0.4688	=	0.261
5	15.2 ÷ 28.3	=	0.537	×	0.4688	=	0.252
6	13.0 ÷ 23.9	=	0.544	×	0.4688	=	0.255
				Total Output		=	1.525 gpm

2. Check to see that all nozzles are within 5% of the rated capacity of these nozzles.

EXAMPLE

Nozzle	Actual gpm ÷ Rated gpm			Subtract 1.00			Multiply = by 100		Percent variation
1	0.253 ÷ 0.250	=	1.012	−1.00	=	0.012	× 100	=	1.2
2	0.250 ÷ 0.250	=	1.00	−1.00	=	0.000	× 100	=	0.0
3	0.254 ÷ 0.250	=	1.016	−1.00	=	0.016	× 100	=	1.6
4	0.261 ÷ 0.250	=	1.044	−1.00	=	0.044	× 100	=	4.4
5	0.252 ÷ 0.250	=	1.008	−1.00	=	0.008	× 100	=	0.8
6	0.255 ÷ 0.250	=	1.020	−1.00	=	0.020	× 100	=	2.0

nozzles. Therefore, find the output of the sprayer over time by measuring how much water the sprayer uses.

Be sure the sprayer remains level, and also be sure to fill the tank to its maximum with clean water. Fill the tank to a level that you can duplicate when refilling. A convenient technique is to fill the tank to the point just before it begins to overflow. Check for leaks around tank seals and in hoses. All nozzles must be clean and operating properly or the results will be inaccurate.

Stand upwind and operate the sprayer at its normal operating pressure. Open the valves to all nozzles and start a stopwatch at the same time. Continue to run the sprayer for several minutes. Then close the valves to all nozzles. Record the elapsed time.

Using the site gauge or dipstick, check to see how much liquid the sprayer used. Otherwise, use a flow meter attached to a low-pressure filling hose, and refill the sprayer to the original level. Record the gallons of water used. This volume is the amount of liquid sprayed during the timed run. Repeat this process two more times to get an average of sprayer output. Determine the output of the sprayer in gallons per minute by using the calculations shown in Sidebar 20.

Swath Width. The final measurement needed to complete calibration is the width of the spray swath being applied by the sprayer. For multiple-nozzle boom-type sprayers, the swath width is the width of the boom plus the distance between one pair of nozzles. You can also calculate swath width by multiplying the number of nozzles by the nozzle spacing:

NUMBER OF NOZZLES × NOZZLE SPACING = SWATH WIDTH

Measure the swath width of a backpack sprayer from the spray pattern produced on the ground in a test run. Keep the nozzle at the height held during an actual application. Maintain this height at all times to prevent variation in swath width.

Determining the Amount of Herbicide to Use. Use tank volume, travel speed, flow rate, and swath width to calculate the total area covered with each tank of material. Knowing this value allows you to determine how much herbicide to put into the tank. Choose from two calculation methods. One is for herbicides applied by the acre and is shown in Sidebar 21. The other is for applications made by the

SIDEBAR 20

Calculating Gallons per Minute for High-Pressure Sprayers

Due to the high pressures of larger sprayers, you cannot collect the spray from individual nozzles. Therefore, find the output of the sprayer over time by measuring how much water the sprayer used. Fill the sprayer to a known level, and then run the sprayer for 2 to 3 minutes. Refill the sprayer, measuring how much water was used. Repeat two more times to get an average output rate. Use a stopwatch to time each run. Follow the steps below to calculate the sprayer's output in gallons per minute.

1. Record the elapsed time during each trial run and the amount of liquid sprayed:

EXAMPLE

Run #	Time	Volume
1	1 min 45 sec	37.5 gal
2	1 min 30 sec	33.5 gal
3	1 min 50 sec	38.0 gal

2. Convert the time from minutes and seconds to minutes by dividing the seconds by 60 and adding this decimal to the minutes.

EXAMPLE

Run #	min	sec	sec ÷ 60	=	min
1	1	45	0.75	=	1.75
2	1	30	0.50	=	1.50
3	1	50	0.83	=	1.83

3. Divide the collected gallons for each run by the minutes, resulting in gallons per minute.

EXAMPLE

Run #	gal ÷ min	=	gpm
1	37.5 ÷1.75	=	21.4
2	33.5 ÷ 1.50	=	22.3
3	38.0 ÷ 1.83	=	20.8

4. Add all the gallon-per-minute figures and divide this total by the number of runs (3 in this example) to get the average gallon-per-minute output.

EXAMPLE

Run #	gpm
1	21.4
2	22.3
3	20.8
Total =	64.5

64.5 ÷ 3 = 21.5 gpm average output

SIDEBAR 21

How Much Herbicide to Put into the Spray Tank (herbicides applied on a per-acre basis)

When making applications to lakes or large ponds use the calculations below to figure how much herbicide to put into the spray tank. This method assumes that you are applying the material on a per-acre basis. Use the rate per acre given by the herbicide label.

1. First, determine the area that can be treated in 1 minute. Divide the spray swath width by 43,560 (the number of square feet in 1 acre) and multiply the result by the travel speed in feet-per-minute. The result will be the acres treated per minute. In the example in Sidebar 16, page 125, travel speed was calculated to be 128.25 feet per minute. Assuming the swath width is 12 feet, the calculation would be:

■ EXAMPLE

12 ft ÷ 43,560 sq ft/ac × 128.25 ft/min = 0.0353 ac/min

In this example, when a swath 12 feet wide is being sprayed, 0.0353 acre is covered in one minute.

2. Next, determine the gallons of liquid being applied per acre. Divide the output in gallons per minute by the acres treated per minute obtained in step 1:

■ EXAMPLE

1.525 gal/min ÷ 0.0353 ac/min = 43.2 gal/ac

3. Then, determine the number of acres that can be treated with a full tank. Divide the actual measured volume of the spray tank (or tanks) by the output in gallons per acre obtained in step 2. Assume that the tank holds 252.5 gallons when filled:

■ EXAMPLE

252.5 gal/tank ÷ 43.2 gal/ac = 5.84 ac/tank

4. Finally, determine how much herbicide to put in the tank. Multiply the number of acres that can be treated per tank by the recommended rate per acre of herbicide; check the herbicide label for this information.

■ EXAMPLE

Herbicide Label Says		Acres per Tank		Amount of Herbicide to Put in Tank
1.5 lb/ac	×	5.84	=	8.76 lb
3 qt/ac	×	5.84	=	17.52 qt
2 gal/ac	×	5.84	=	11.68 gal
1 pt/ac	×	5.84	=	5.84 pt

square foot, such as for small ponds, and is shown in Sidebar 22.

Sidebar 23 is an example of how to combine calibration formulas onto a worksheet for in-field use. To prevent waste of herbicide material, accurately measure the area you plan to treat. Then, mix only the amount of chemical needed. See Sidebars 24 through 27 for ways to measure or estimate the size of variously-shaped bodies of water.

Metered Flow Applications

To determine how much herbicide to apply to flowing water as a metered flow application you must calculate the volume of water in cubic feet per second (cfs) moving downstream. This requires estimating

- the average depth of the moving water throughout the treatment area
- the average width of the body of water
- the speed of the moving water in feet per second

Once these features of the water are known use the following formula to calculate the volume in cubic feet per second:

VOLUME (CFS) = AVERAGE WIDTH (FEET) × AVERAGE DEPTH (FEET) × SPEED (FEET/SECOND) × 0.9

The constant 0.9 is a correction factor to adjust for the actual speed of the moving water. Since the speed measurement is taken at the surface, this factor is used to average the speed throughout the depth of the water.

After you have calculated the volume in cubic feet per second of the flowing water, follow the herbicide label instructions for the appropriate application rate. This might include a parts-per-million concentration as described below.

Parts-per-Million Dilutions

Label instructions require that you mix certain herbicides in parts-per-million (ppm) concentrations. The ppm designation represents the parts of herbicide active ingredient per million parts of water being treated. These are computed on a weight/weight (w/w) basis. The label usually indicates, in table format, the appropriate amount of herbicide formulation for a desired concentration of active ingredient. You will need to calculate the volume of water being treated in acre-feet. To do this, first calculate the total volume in acre-feet of the body of water. This is accomplished by first calculating the size, in acres, of the surface area of the body of water. Then calculate its average depth in feet. The volume in acre-feet is equal to the average depth in feet multiplied by the surface area in acres:

VOLUME (ACRE-FEET) = AVERAGE DEPTH (FEET) × SURFACE AREA (ACRES)

Once you know the acre-feet, you can determine how much herbicide active ingredient (a.i.) you will need to prepare a specific concentration by using the following formula:

HERBICIDE A.I. = CONCENTRATION (PPM) × VOLUME (ACRE-FEET) × 2.7

The number 2.7 in the above formula is a constant. One acre-foot of water weighs 2,700,000 pounds. Therefore, 2.7 pounds of a substance in 1 acre-foot of water would make a concentration of 1 ppm.

All herbicides are formulated with other materials (inert ingredients), so the material you buy is not all active ingredient. Therefore, first check the "Contents" section of the label to find out what percentage of active ingredient is in the formulation. Once you know this, use the formula below to calculate the amount of *formulated* herbicide to use.

FORMULATED HERBICIDE = CONCENTRATION (PPM) × VOLUME (ACRE-FEET) × 2.7 ÷ A.I. (%)

SIDEBAR 22

How Much Herbicide to Put into the Spray Tank (herbicides applied by the square foot)

1. Determine how many square feet can be treated in 1 minute. Multiply the speed as determined by the procedures in Sidebar 16, page 125, by the swath width. In this example, assume a single-nozzle hand-operated sprayer is being used to apply a swath width of 2.5 feet at a speed of 128.25 feet per minute.

EXAMPLE

128.25 ft/min × 2.5 ft = 320.63 sq ft/min

2. Next, determine the volume of spray, in gallons, that will be applied to 1 square foot. Divide the gallon-per-minute output of the sprayer by the square-feet-per-minute figure obtained in step 1. For this example, assume that the backpack unit sprays 0.05 gallons per minute.

EXAMPLE

0.05 gal/min ÷ 320.63 sq ft/min = 0.000156 gal/sq ft

3. Then, find out how many square feet can be sprayed with one tank. Divide the volume of spray in gallons per square foot into the measured tank capacity. For this example assume that the tank holds 3 gallons.

EXAMPLE

3 gal/tank ÷ 0.000156 gal/sq ft = 19,230 sq ft/tank

4. Finally, determine how much herbicide to put into the tank. First, read the herbicide label; it will tell you the amount of herbicide to apply. Normally, the label will tell you how much to apply per square foot (or per 100 or 1,000 square feet) or per acre.

EXAMPLE A

If the label gives the dosage rate per 1, 100, or 1,000 square feet, multiply that rate by the square-feet-per-tank determined in step 3:

Herbicide Label Says	×	Square Feet per Tank	=	Amount of Herbicide to Put in Tank
3 fl oz per 1,000 sq ft	×	19,230	=	57.69 fl oz
3/4* fl oz per 1,000 sq ft	×	19,230	=	14.42 fl oz
1 oz per 1,000 sq ft	×	19,230	=	19.23 oz

*The fraction 3/4 is converted to its decimal equivalent, 0.75, to complete this calculation.

EXAMPLE B

If the herbicide label gives the dosage rate in units of herbicide per acre, convert square feet per tank (from step 3) to acres per tank by dividing it by 43,560 (there are 43,560 square feet in 1 acre):

19,230 sq ft/tank ÷ 43,560 sq ft/ac = 0.441 ac/tank

Then, multiply the labeled rate per acre by the acres-per-tank figure:

Herbicide Label Says	×	Acres per Tank	=	Amount of Herbicide to Put into Tank
1.5 lb/ac	×	0.441	=	0.661 lb (10.6 oz)
3 qt/ac	×	0.441	=	1.32 qt (42.2 fl oz)
2 gal/ac	×	0.441	=	0.882 gal (7.1 pt)
1 pt/ac	×	0.441	=	0.441 pt (7.1 fl oz)

SIDEBAR 23

Calibration Worksheet

Operator: ____________________ Date: __________________ Sprayer Type:______________

CHECK

- ☑ Filter screens and strainers clean?
- ☑ Tank clean and free of scale and sediment?
- ☑ Pressure gauge operating?
- ☑ Nozzles working properly?
- ☑ Sprayer operating pressure = _______ psi

GALLONS PER HOUR

(Method I—Measuring Sprayer Output)

Nozzle Number	Output (gallons per minute)	×	Minutes per Hour	=	Gallons per Hour
________	__________	×	60	=	________
________	__________	×	60	=	________
________	__________	×	60	=	________
			Total gallons per hour	=	________

GALLONS PER HOUR = __________

GALLONS PER HOUR

(Method 2—Refilling Spray Tank)

1. Fill sprayer to verifiable level.
2. Run sprayer for a measured period of time (T), spraying under the same conditions as in the aquatic area.

   T = __________

3. Refill sprayer, measuring the amount of water used in gallons (GAL).

   GAL = __________

4. Calculate gallons per hour:

   gallons per hour = (GAL × 60) ÷ T

GALLONS PER HOUR = __________

MILES PER HOUR

1. Establish distance (D) in feet.

D = __________

2. Measure elapsed time for sprayer to travel the distance.

Make 3 runs and average results:

a. First run: Time = _____ minutes.
b. Second run: Time = _____ minutes.
c. Third run: Time = _____ minutes.

3. Average of three runs: (T) = ____ minutes.

4. Calculate miles per hour:

MPH = distance (D) ÷ time (T) ÷ 88

MILES PER HOUR = __________

ACRES PER HOUR

1. Measure swath width (W) in feet: W = ________

2. Calculate miles per acre:

miles per acre = (43,560 ÷ W) ÷ 5,280

MILES PER ACRE = __________

3. Calculate acres per hour:

acres per hour = miles per hour ÷ miles per acre

ACRES PER HOUR = __________

GALLONS PER ACRE

gallons per acre = gallons per hour ÷ acres per hour

GALLONS PER ACRE = __________

ACRES PER TANK

Tank size = ______ gallons per tank

acres per tank = gallons per tank ÷ gallons per acre

ACRES PER TANK = __________

AMOUNT OF PESTICIDE PER TANK

Recommended amount of pesticide per acre = ________________

pesticide per tank = pesticide per acre × acres per tank

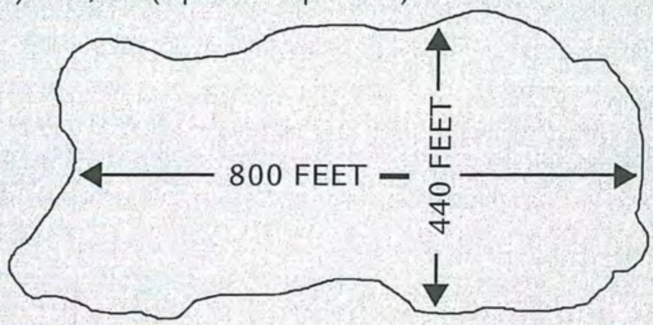
PESTICIDE PER TANK = __________

SIDEBAR 24

Calculating the Acreage of a Rectangular Pond

To calculate the acreage of a small rectangular pond or lake, use this formula:

surface acres = length (feet) × width (feet) ÷ 43,560 (square feet per acre)



EXAMPLE

What is the acreage of the more or less rectangular pond, illustrated here, that measures 800 by 440 feet?

SOLUTION

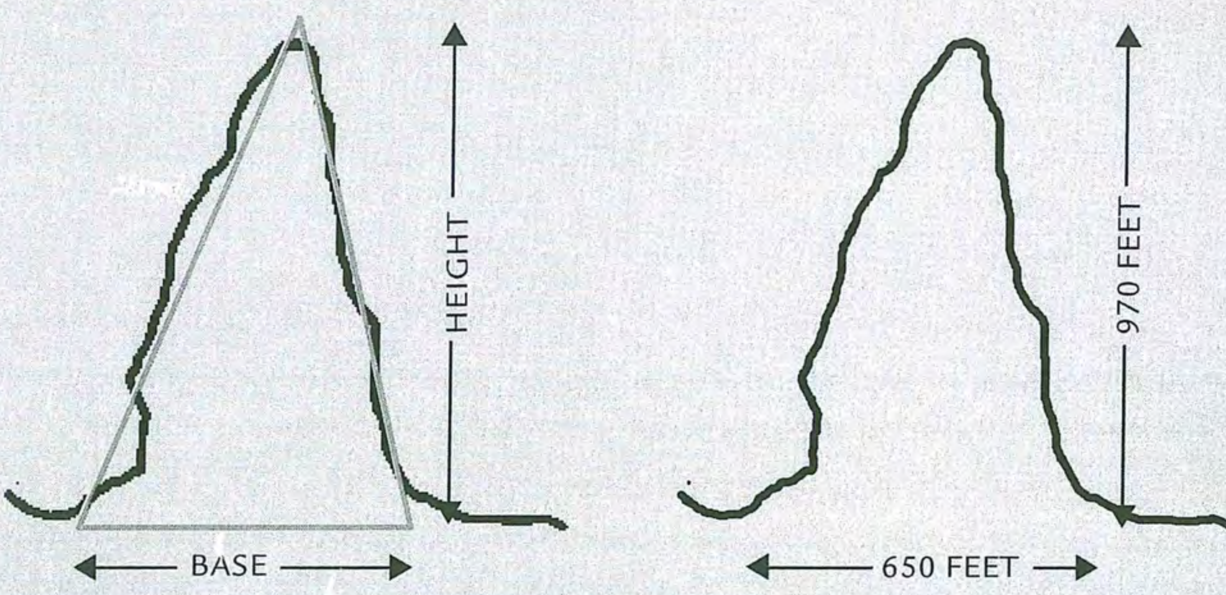
surface acres = 800 feet × 440 feet ÷ 43,560 square feet = 8.1 acres

SIDEBAR 25

Calculating the Acreage of a Triangular-Shaped Pond or Cove

To calculate the acreage of a triangular-shaped pond or cove, use this formula:

area of a triangle (acres) = 0.5 × base (feet) × height (feet) ÷ 43,560 (square feet per acre)



EXAMPLE

What is the surface area of the cove, illustrated above, that measures 650 feet at the base and is 970 feet long?

SOLUTION

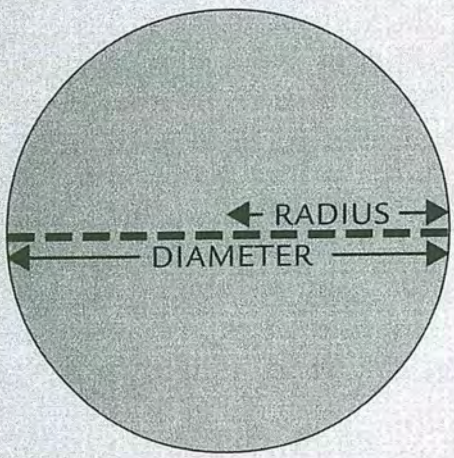
area = 0.5 × 650 feet × 970 feet ÷ 43,560 square feet = 7.24 acres

SIDEBAR 26

Calculating the Acreage of a Circular Pond

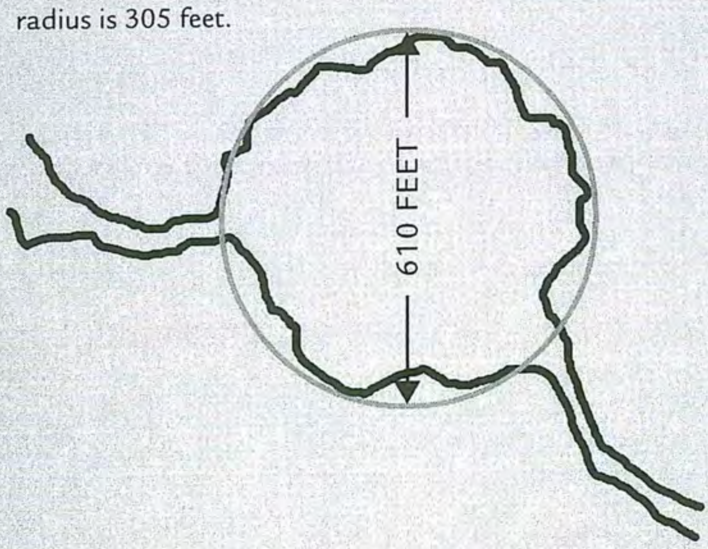
The area of a circle is determined by using the equation area = πr^2, where $\pi = 3.14$ and r = one half of the diameter of the circle.

area of a circle (acres) = 3.14 × radius squared (feet) ÷ 43,560 (square feet per acre)



EXAMPLE

Estimate the surface area, in acres, of the pond illustrated below. The diameter of this pond is 610 feet, therefore it's radius is 305 feet.



SOLUTION

area = 3.14 × 305 feet × 305 feet ÷ 43,560 square feet = 6.7 acres

SIDEBAR 27

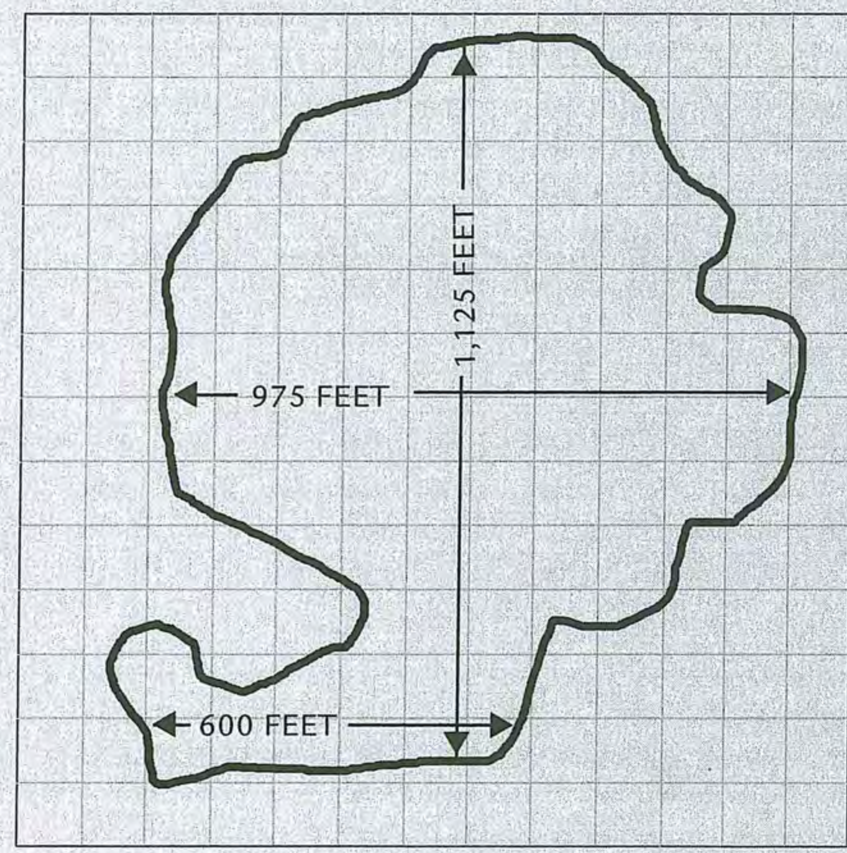
Calculating the Acreage of an Irregularly-Shaped Lake

The shape of many lakes does not fit into the rectangular, triangular, or circular description. If this is the case, you can estimate the areas as follows.

1. Sketch the outline of the lake on a sheet of graph paper, closely estimating the lake's length, width, and dimensions of coves and other features.
2. Draw a rectangle around the lake shape, being careful to include all squares that contain any part of the lake. Multiply the length by the width of this rectangle and divide by 43,560 square feet. This is the total acres occupied by the rectangle.
3. Count the number of squares of the graph that are occupied in whole or in part by the lake. Divide this number by the total number of squares within the rectangle.
4. Multiply this fraction of the rectangle occupied by the lake by the total area of the rectangle. This gives you the number of acres occupied by the lake.

EXAMPLE

Find the area of this irregularly-shaped lake. Each square of the graph is equal to 100 feet.



SOLUTION

rectangle area = 1,300 feet × 1,300 feet ÷ 43,560 square feet = 38.8 acres

number of squares in the rectangle = 169

number of squares totally or partially covered by the lake = 96

96 lake squares ÷ 169 total squares = 0.57

area of lake = 38.8 acres × 0.57 = 22.12 acres

SIDEBAR 28

Calculating a Percentage Solution with a Liquid Formulation

To prepare a percentage solution using liquid formulations, you need to know the volume of the spray tank, the weight of active ingredient (a.i.) per gallon of formulation, and the weight of a gallon of water. The weight of a gallon of water is a constant, approximately 8.34 pounds. Assume you have measured the volume of the spray tank and found that it holds 264.5 gallons of water. You are given a recommendation to apply a 1% solution of glyphosate for control of aquatic weeds, using a high-pressure sprayer with a hand-held spray nozzle. The formulation of glyphosate that you are to use contains 5.4 pounds of active ingredient per gallon.

1. Find the total weight of the liquid in the filled tank by multiplying 264.5 gallons by 8.34 pounds per gallon:

■ EXAMPLE

264.5 gal × 8.34 lb/gal = 2,205.93 lb

2. Multiply this weight by 0.0 (1%) to determine the weight of a.i. required to mix a 1% solution:

■ EXAMPLE

2,205.93 × 0.01 = 22.06 lb

3. Divide the required weight of a.i. by the weight of a.i. in the formulation. The result is the number of gallons of liquid formulation that should be added to 264.5 gallons of water to achieve a 1% solution:

■ EXAMPLE

22.06 lb a.i. ÷ 5.4 lb a.i./gal = 4.1 gal formulation

In this example, one tank of liquid should contain 4.1 gallons of glyphosate formulation. The total volume of water combined with the glyphosate formulation should equal 264.5 gallons, the capacity of the tank. You would therefore use 260.4 gallons of water and 4.1 gallons of formulated glyphosate.

Note: These calculations give a close approximation of the amount of liquid formulation to add to the tank to achieve a known percentage solution. The mathematics for a more exact figure are more complex and unnecessary for this type of work.

Percentage Solutions

Sometimes label recommendations require that the herbicide be mixed in the spray tank as a percentage solution. You mix the active ingredient with a specific amount of water to get a known concentration, regardless of the sprayer output rate. In these cases, labels usually tell you how much formulated herbicide to mix with certain volumes of water to achieve the desired percentage. You mix percentage solutions on a weight/weight (w/w) basis, that is, pounds of active ingredient per pound of water. Sidebar 28 provides an example of calculating a percentage solution with liquid formulations. Sidebar 29 shows an example for dry formulations.

Calibration Methods for Granule Application Equipment

The techniques for calibrating granule applicators are similar in many ways to those used for liquids. However, you must calibrate the granule applicator for each type of granular herbicide you apply. Also, recalibrate this equipment each time weather conditions change. Granules vary in size and shape from one herbicide to the next, influencing their flow rate from the applicator hopper. Temperature and humidity also influence granule flow.

Before beginning to calibrate a granule applicator, be sure that it is clean and all parts are working properly. Most equipment requires periodic lubrication. When servicing or adjusting granule applications, always wear rubber gloves to prevent contact with herbicide residues. Calibrating granule applicators involves using actual herbicides, so wear all the label-prescribed personal protective equipment.

You must measure three variables when calibrating a dry applicator:

- travel speed
- output rate
- swath width

SIDEBAR 29

Calculating Percentage Solutions with Dry Formulations

Dry formulations require similar calculations to determine percentage solutions. First, from the label, determine the percent of active ingredient (a.i.) in the dry formulation. Assume for this example that it is 75% a.i.; 1 pound of dry formulation would contain 0.75 pound of pesticide a.i. You need to mix a 1% spray solution of this formulation in a 264.5-gallon tank.

1. Find the total weight of the liquid in the filled tank by multiplying 264.5 gallons by 8.34 pounds per gallon:

EXAMPLE

264.5 gal × 8.34 lb/gal = 2,205.93 lb

2. Multiply this weight by 0.01 (1%) to determine the weight of a.i. required to mix a 1% solution:

EXAMPLE

2,205.93 × 0.01 = 22.06 lb

3. Divide the weight of a.i. by the decimal equivalent of the percentage of a.i. in the formulation. The result is the number of pounds of formulation that should be added to 264.5 gallons of water to achieve a 1% solution:

EXAMPLE

22.06 lb ÷ 0.75 = 29.41 lb formulation

Add 29.41 pounds of wettable powder to 264.5 gallons of water to achieve a 1% solution.

Travel Speed. Determine travel speed in feet per minute in the same manner as you would for liquid applicators. Follow the instructions given on page 125. Fill the applicator hoppers so you can measure speed under actual operating conditions.

Output Rate. To determine the rate of output, fill the hopper or hoppers with the granular herbicide. Most granule applicator hoppers have ports with adjustable openings for granules to pass through. Refer to the manufacturer's instructions to determine the approximate opening for the rate and speed you need. Once you set the approximate opening, determine the actual output rate. Fill the hopper or hoppers to a known level and operate the equipment for a measured time. When finished, weigh the quantity of granules required to refill the hoppers to their original levels. Use the calculations shown in Sidebar 30 to compute the output rate. Perform this step in an area where the herbicide will actually be applied. To avoid overapplication, do not treat the test area again once your equipment is calibrated.

Swath Width. To measure the swath width, operate the equipment at the speed it would operate under actual conditions, but in a calm area where you can see the spread of the granules on the water's surface. If possible, keep the boat at a fixed location. Physically measure the swath width with a measuring tape.

Application Rate. Use Sidebar 31 to calculate the actual rate of granules being applied per acre or other unit of area. If your calculations do not correspond to the labeled rate, adjust

SIDEBAR 30

Calculating Granule Output Rate by Collecting a Measured Amount Over a Known Period of Time

When applying granular herbicides in an aquatic area, follow the instructions below to calculate the rate of output from your spreaders:

1. Fill the hopper or hoppers to a known level with granules.
2. Operate the equipment for a measured period of time at a known speed.
3. Weigh the amount of granules required to refill the hopper or hoppers to their original level. If multiple hoppers are being used, be sure each is applying approximately the same amount of granules. If a significant variation exists, adjust the ports and repeat steps 1 through 3.

■ EXAMPLE

In this example, six applicators are used together on a boom. They have been adjusted so that they all apply approximately the same amount of granules:

Hopper Number	Operating Time	Weight of Granules
1	2.5 minutes	6.2 lb
2	2.5	6.1
3	2.5	6.1
4	2.5	6.3
5	2.5	6.1
6	2.5	5.9

Total Output = 36.7 lb

4. Convert the output to pounds-per-minute by dividing the total weight from all hoppers by the length of time they were operated.

■ EXAMPLE

36.7 lb ÷ 2.5 min = 14.68 lb/min

5. Use the technique shown in Sidebar 31, page 142, to calculate the rate per acre or other unit of area.

the equipment and repeat the calibration procedure. Motorized and hand-operated applicators apply granules at a fixed output independent of your travel speed in the water. When your speed increases, you apply fewer granules per unit of area. When your speed decreases, you apply more material.

SIDEBAR 31

Calculating the Granule Application Rate per Acre or Other Unit of Area

Once you know the output rate of your granule applicator, the swath width, and the travel speed, you can compute the application rate per acre or other unit of area. Follow the steps listed below.

1. Determine the number of acres per minute being treated by dividing the swath width by 43,560 (the number of square feet in an acre) and multiplying the result by the speed of travel. In this example the swath width is 30 feet and the application speed is 352 feet per minute (4 miles per hour).

■ EXAMPLE

30 ft (swath) ÷ 43,560 sq ft/ac × 352 ft/min = 0.242 ac/min

2. Determine the pounds of formulated herbicide being applied per acre by dividing the output rate of the granule applicator (as computed from the calculations performed in Sidebar 30) by the acres-per-minute result obtained in step 1. This example uses 44.42 pounds per minute as the output rate.

■ EXAMPLE

44.42 lb/min ÷ 0.242 ac/min = 183.6 lb/ac

REVIEW QUESTIONS

(answers on page 145)

1. If you cannot identify a plant, you should obtain help from the:
- ☐ a. County agricultural commissioner, local UC farm advisor, or the California Department of Food and Agriculture
- ☐ b. California Department of Fish and Game
- ☐ c. Landowner
- ☐ d. California Department of Boating

2. Bottom applications to control submersed weeds are usually applied during the:
- ☐ a. Spring
- ☐ b. Summer
- ☐ c. Winter
- ☐ d. Fall

3. Granular applications are used to control:
- ☐ a. Emersed weeds such as cattail and bulrush
- ☐ b. Free-floating weeds such as duckweed and waterhyacinth
- ☐ c. Submersed weeds such as egeria and coontail
- ☐ d. Emersed and free-floating weeds

4. Sometimes a large volume of herbicide is applied at one location into moving water. This large single application is known as a:
- ☐ a. Dose
- ☐ b. Slug
- ☐ c. Shot
- ☐ d. Treatment

5. Selecting the right spray nozzles is important because nozzles:
- ☐ a. Determine which herbicide can be used
- ☐ b. Determine the size of an area that can be treated
- ☐ c. Control the pressure in the spraying system
- ☐ d. Determine the spray pattern, angle, droplet size, and flow rate

6. Nozzles that produce fine droplets are usually recommended for:
- ☐ a. Free-floating weeds
- ☐ b. Submersed weeds
- ☐ c. Postemergent applications
- ☐ d. Preemergent applications

7. Nozzles that produce coarse droplets are especially useful when:
- ☐ a. Uniform coverage is needed
- ☐ b. Spraying dense foliage
- ☐ c. Drift is a problem
- ☐ d. There is no wind

8. Equipment designed for spraying small areas and for making spot treatments includes:
- ☐ a. Hand-held spray gun applicators, compressed air sprayers, and hand-operated powered backpack sprayers
- ☐ b. Fixed-wing aircraft and helicopters
- ☐ c. Motorboats and airboats
- ☐ d. Centrifugal spreaders

9. In an aquatic herbicide application being made from a boat, which of the following factors has the *least* effect on the rate of chemical application?
- ☐ a. Boat speed
- ☐ b. Width of the spray swath
- ☐ c. Herbicide type
- ☐ d. Pump output

10. Which of the following would *not* be an advantage to having your application equipment properly calibrated?
- ☐ a. Calibration helps to prevent the waste of time and money
- ☐ b. Proper calibration helps to assure effective pest control
- ☐ c. Calibration allows you to apply significantly higher rates of herbicides
- ☐ d. Proper calibration helps to assure that application rates are within the legal limits

11. Improper calibration of herbicide application equipment may result in:
- ☐ a. Damage to the environment
- ☐ b. Increased efficacy
- ☐ c. Savings of time and money
- ☐ d. Fewer environmental problems

12. A metered flow application is:
- ☐ a. The closed-system metering of an herbicide concentrate being put into a spray tank
- ☐ b. The measurement of a surface spray being applied to a lake
- ☐ c. The injection of an herbicide near the bottom of a lake or pond
- ☐ d. Continuous application of an herbicide into flowing water from an upstream location

13. Which of the following *is not* one of the four factors that needs to be measured to calibrate a sprayer for liquid applications?
- ☐ a. Size of the treatment area
- ☐ b. Tank capacity
- ☐ c. Flow rate
- ☐ d. Travel speed

14. The spray swath width produced by a boom having 12 evenly spaced flat fan nozzles can be calculated by:

- ☐ a. Multiplying the nozzle spacing by 12
- ☐ b. Dividing the nozzle spacing by 12
- ☐ c. Measuring the boom width and dividing by 12
- ☐ d. Measuring the boom width and adding 12

15. A calibrated sprayer has been found to be able to spray 3.5 acres with one tank. How much herbicide must be put into the tank to apply the herbicide at 5 quarts per acre?

- ☐ a. 7.5 quarts
- ☐ b. 5.5 quarts
- ☐ c. 12.5 quarts
- ☐ d. 17.5 quarts

16. A pond has a surface area of 6 acres and an average depth of 5 feet. How many acre-feet of water are in this pond?

- ☐ a. 3
- ☐ b. 15
- ☐ c. 30
- ☐ d. 300

17. If the weight of 1 acre-foot of water is 2,700,000 pounds, how many pounds of herbicide active ingredient must you apply per acre-foot to achieve a 2 ppm concentration?

- ☐ a. 54
- ☐ b. 27
- ☐ c. 5.4
- ☐ d. 2.7

18 If there are 5 pounds of active ingredient per gallon of liquid herbicide, how many total gallons must you apply to a 30 acre-foot pond to achieve 1 pound of active ingredient per acre-foot of water?

- ☐ a. 1.2
- ☐ b. 5
- ☐ c. 6
- ☐ d. 15

ANSWER SHEET FOR REVIEW QUESTIONS

Chapter 1

1. d
2. d
3. b
4. c
5. a
6. b
7. b
8. c
9. d
10. c
11. d
12. c
13. d
14. c
15. b
16. c

Chapter 2

1. b
2. a
3. d
4. c
5. b
6. d
7. a
8. c
9. d
10. b
11. d
12. d
13. b

Chapter 3

1. a
2. a
3. c
4. a
5. b
6. a
7. c
8. a
9. d
10. a
11. d
12. d
13. a
14. d
15. c
16. c
17. b
18. d

Chapter 4

1. a
2. b
3. c
4. b
5. c
6. b
7. c
8. c
9. b
10. a

Chapter 5

1. d
2. b
3. b
4. b
5. a
6. a
7. c
8. d
9. b
10. b
11. d
12. c
13. c
14. a
15. c
16. b
17. c
18. d

Chapter 6

1. a
2. a
3. c
4. b
5. d
6. c
7. c
8. a
9. c
10. c
11. a
12. d
13. a
14. a
15. d
16. c
17. c
18. c

List of Aquatic Weed Photos and Illustrations

Glossary

abiotic. nonliving factors, such as wind, water, temperature, and soil type and texture.

abiotic disease. a disease caused by factors other than living organisms.

absorb. to take up into the tissues of a plant or animal.

acidifier. an adjuvant used to lower the pH of (to acidify) the water being mixed with a pesticide.

acidulator. see *acidifier*.

acre-foot. amount of water needed (325,900 gallons) to cover 1 acre (43,560 square feet) 1 foot deep.

active ingredient (a.i.). the material in the pesticide formulation that actually destroys or inhibits the target pest or performs the desired function.

acute toxicity. the quality or potential of a substance to cause injury or illness shortly after exposure to a relatively large dose.

adjuvant. a material added to a pesticide mixture to improve or alter the deposition, toxic effects, mixing ability, persistence, or other qualities of the active ingredient.

adsorb. to take up and tightly bind to the surface of an object.

aeration. the process of introducing air into water to help control the buildup of algae and other aquatic weeds, bottom sludge, and aquatic odors.

aerobic. living, active, or occurring in the presence of free oxygen; opposite of *anaerobic*.

aerosol. very fine liquid droplets or dust particles, often emitted from a pressurized can or aerosol-generating device.

alga. a nonvascular, chlorophyll-containing plant without true roots, leaves, or flowers (plural: *algae*).

algaecide. a chemical used to control algae.

algal bloom. excessive or dense growths of a single or several species of algae; usually of relatively short duration, but may occasionally persist for extended periods.

allelopathy. the production of chemicals by one plant that retards the growth or development of another plant.

amphibian. a cold-blooded vertebrate such as a frog, toad, or salamander.

anaerobic. living in the absence of air; opposite of *aerobic*.

annual. a type of plant that passes through its entire life cycle in 1 year or less.

anther. the top portion of the stamen that contains the pollen; usually elevated by means of a *filament*.

aquaculture. the cultivation of marine or freshwater organisms under controlled environmental conditions.

aquatic plant. a plant that grows on, in, or under water.

aquatic weed. an *aquatic plant* that is unwanted at a specific place or time, characterized by prolific growth and reproduction. Large numbers of aquatic weeds can create economic, navigational, and recreational problems and displace native vegetation.

aqueous. indicating the presence of water in a solution or environment.

aqueous solution. a liquid pesticide formulation in which the active ingredient and all other components are dissolved in water.

aqueous suspension. see *flowable.*

arthropod. an animal having jointed appendages and an external skeleton, such as an insect, a spider, a mite, a crab, or a centipede.

asexual reproduction. plant reproduction that occurs by vegetative means, such as from stem fragments, stolons, rhizomes, root crowns, tubers, turions, or spores.

awn. a slender, bristlelike appendage usually found at the tip of another plant structure.

axil. the upper angle between a twig or leaf and the stem from which it is growing.

axillary bud. a bud formed in an *axil.*

back siphoning. the illegal process that permits pesticide-contaminated water to be sucked from a spray tank back into a well or other water source. Back siphoning is prevented by providing an air gap or a check valve in the pipe or hose used to fill a spray tank.

backpack sprayer. a small portable sprayer carried on the back of the person making the pesticide application. Some knapsack, or backpack, sprayers are hand-operated and others are powered by small gasoline engines.

ballast. water taken into a special holding chamber and used to balance a ship to improve its stability and control.

band treatment. herbicide application to a continuous, linear area, such as on or along a crop row, rather than over the entire field.

basal treatment. a treatment applied to the stems of woody plants at or just above ground level.

beneficial. pertaining to plants, insects, and other organisms that are helpful in some way.

benthic. pertaining to all the plants and animals living on or near the bottom of a body of water.

berm. a raised edge or shoulder running along the edge of a pond to prevent direct surface runoff.

biennial. a plant that completes its life cycle in 2 years and usually does not flower until the second season.

bioaccumulation. the gradual buildup of certain pesticides within the tissues of living organisms (including humans) due to feeding on other plants or animals that have pesticide residues in their tissues.

biochemical. pertaining to any chemical reaction that takes place within the cells or tissues of living organisms.

biological control. the action of parasites, predators, pathogens, or competitors in maintaining another organism's numerical density at a lower level than would occur in their absence.

biological degradation. the breakdown of a pesticide due to the activities of living organisms, especially bacteria and fungi.

biotic. pertaining to living organisms.

biotype. a group of organisms within the same species having some hereditary characteristics that differ from other organisms of that species. For example, hydrilla has two biotypes, *dioecious* and *monoecious*.

bloom. extremely heavy growths of phytoplankton that color the water or form surface scum. Excessive blooms can lead to oxygen depletion and fish kills.

bog. wet, spongy ground; marshy areas.

boom. a structure attached to a truck, tractor, or other vehicle, or held by hand, to which spray nozzles are attached.

brackish. water containing high concentrations of salts and other dissolved minerals.

branched algae. a group of submersed, multicelled algae resembling vascular plants due to their branching growth and holdfast structures (as opposed to roots) that anchor them to the sediment.

broadcast application. a method of applying granular pesticides by dispersing them over a wide area, using a spinning disc or other mechanical device.

broadleaf. one of the major plant groups, known as *dicots*, characterized by net-veined leaves that are usually broader than grass leaves.

bud. a small swelling or projection on a plant from which a shoot, a cluster of leaves, or flowers develop.

buffer area. a part of a pest-infested area that is not treated during a pesticide application in order to protect adjoining areas from pesticide hazards.

bulb. an underground storage organ, composed chiefly of enlarged, fleshy leaf bases.

calibration. the process used to adjust the output of pesticide application equipment so that the proper amount of pesticide can be applied to a given area.

carcinogenic. pertaining to a substance that has the ability to produce cancer in test animals or human beings.

carrier. the water or oil that a pesticide is mixed with prior to application.

catkin. the flowering head of a cattail and certain other plant species.

Caution. the signal word used on labels of pesticides classified as either slightly toxic or relatively nontoxic. These pesticides an have an oral LD_{50} greater than 500 and a dermal LD_{50} greater than 2,000.

charophyte. a branched alga that is anchored to the bottom; sometimes confused with vascular plants.

chemical degradation. the breakdown of a pesticide by oxidation, reduction, hydrolysis, or other chemical means.

chemical name. the scientific name of a pesticide active ingredient. The name complies with accepted guidelines established by chemical societies.

chlorophyll. the green photosynthetic substance in plants that allows them to capture solar energy.

chlorosis. a yellowing or bleaching of normally green leaves due to loss of *chlorophyll*; a nutrient deficiency, disease, pest damage, or other disorder.

chlorotic. referring to foliage that has lost its green color and turns yellow.

chronic toxicity. the quality or potential of a substance to cause injury or illness, usually after repeated exposure to small doses over an extended period of time.

cfs. cubic feet per second.

common name. (1) *when referring to an organism:* the recognized, nonscientific name given to plants or animals; (2) *when referring to a pesticide:* an abbreviated name applied to a pesticide active ingredient usually agreed upon by the

American National Standards Institute and the International Organization for Standardization.

compatible. the condition in which two or more pesticides mix without unsatisfactory chemical or physical changes.

competition. the struggle between pests and nonpests for the same resources, such as water, light, nutrients, or space.

competitive ability. in aquatic weeds, the ability to compete for available nutrients and light, and the tendency to crowd out other plants.

concentration. the amount of active ingredient of a pesticide in a quantity of diluent, expressed as percent, pounds per gallon, fluid ounces per gallon, etc.

contact herbicide. an herbicide that causes localized injury to plant tissue at the point where the herbicide touches the tissue.

corm. an underground, enlarged, solid stem filled with nutrients and covered by a few thin and membranous scaly leaves.

cotyledon. the first leaf or pair of leaves of a sprouted seed. Grasses (*monocots*) have a single cotyledon while broadleaved plants (*dicots*) have a pair of cotyledons.

crown. that part of a stem at or just below the surface of the ground.

culm. the hollow stem of grasses and sedges.

cultural control. a control method, sometimes called preventive control or habitat alteration, that alters the environment to inhibit the growth of certain aquatic weeds or other pests.

cuticle. a waxy, protective layer on the surfaces of the leaves and stems of plants.

***Danger*.** the signal word used on labels of pesticides that have an oral LD_{50} less than 50 or a dermal LD_{50} less than 200, or those having specific, serious health or environmental hazards.

deciduous. referring to trees and shrubs that lose their leaves in the fall.

decumbent. a plant in which stems grow flat on the ground, but the ends or tips ascend upward.

defoaming agent. an adjuvant that eliminates foaming of a pesticide mixture inside the spray tank.

degradation. the breakdown of a pesticide into an inactive or less active form. Environmental conditions, impurities, or microorganisms can contribute to the degradation of pesticides.

dehydration. the process in which a plant or animal loses water or dries up.

dermal. pertaining to the skin; one of the major ways pesticides can enter the body and possibly cause injuries.

desiccant. a pesticide that destroys target pests by causing them to lose moisture.

diatom. an alga that has structured cell walls containing silica.

dicotyledon. a broadleaved plant, also known as a *dicot*, whose seedling has two leaves, such as waterlily, American lotus, Eurasian watermilfoil, and alligatorweed.

diluent. any gas, liquid, or solid material used to dilute or reduce the concentration of an active ingredient in a pesticide formulation.

dioecious. pertaining to plants that have the male and female sexual elements in separate individuals, such as male and female hydrilla plants.

dispersible granule. see *water-dispersible granule*.

dormant. a state in which growth and other activity stops temporarily in certain plants, plant parts, microorganisms, and animals.

draglining. the process of dragging the bottom sediment with special devices to remove unwanted vegetation.

drawdown. an aquatic weed management technique that involves draining a body of water to expose the rooted and submersed weeds to drying, heating, or freezing.

dredging. deepening a body of water or water channel by scooping out and removing some of the sediment.

drift. the movement of pesticide dust, spray, or vapor away from the application site, usually by wind.

efficacy. effectiveness; the ability of a pesticide to produce a desired effect on a target organism.

effluent. water discharge, often referring to water that is leaving a sewage treatment pond or facility.

emergence. the event in seedling or perennial growth when a shoot pushes through the soil surface and becomes visible.

emersed. an aquatic plant that extends above the water surface and is rooted in the sediment at water depths less than 2 to 3 feet.

emulsifiable concentrate (EC). a single-phase liquid formulation that forms an emulsion when added to water.

emulsifier. an adjuvant that promotes the suspension of one liquid in another.

emulsion. droplets of petroleum-based liquids (oils) suspended in water.

endangered species. a rare or unusual species of living organism on the brink of extinction whose continued existence is threatened by people's activities, including the use of some types of pesticides.

endemic. a plant that is native to a particular country or region.

eradication. the pest management strategy that attempts to eliminate all members of a pest species from a defined area.

ergot. structures of fungi that grow on plants or plant parts, usually associated with the seed heads.

erosion. movement of soil and associated materials from an area, principally by water and wind.

eutrophic. nutrient enriched, such as a body of water that receives runoff from a fertilized field or overflowing septic system.

exclusion. a pest management technique that uses physical or chemical barriers to prevent certain pests from getting into a defined area.

exotic. something that is not native to the area, such as a pest from another country.

exposure. to come in contact with a pesticide or pesticide residues.

federal noxious weed. a weed classification of the U.S. Department of Agriculture. Such weeds cannot be moved into or through the United States without written permission from the USDA Animal and Plant Health Inspection Service (APHIS).

FIFRA. the Federal Insecticide, Fungicide, and Rodenticide Act; the federal law that regulates pesticide manufacture and use in the United States.

filament. in a flower, the stalk that bears the anther.

filamentous alga. an alga that grows into threadlike filaments, strands, or nets, commonly referred to as pond scum or pond moss.

filamentous fungus. a fungus having an end-to-end arrangement of cells that form colorless, branched filaments.

floating plant. a free-floating or anchored aquatic plant adapted to grow with most of its vegetative tissue at or above the water surface and lowering or rising with the water level.

flowable (F). a two-phase formulation that contains solid pesticide particles suspended in liquid, and forms a suspension when added to water in the spray tank.

flower. the part of a plant containing or consisting of the organs of reproduction.

foliage. the leaves of plants.

foliar application. application of a pesticide to the exposed or emersed leaves of target plants.

formulation. (1) a pesticidal preparation supplied by a manufacturer for practical use; (2) the process, carried out by manufacturers, of preparing pesticides for practical use.

free-floating plant. an aquatic plant that floats freely on or beneath the water surface; not rooted in the sediment.

fruit. the developed ovary of the flower containing ripe seeds.

general-use pesticide. a pesticide that has been designated for use by the general public.

genus. a taxonomic group consisting of closely related species (plural: *genera*).

gpa. gallons per acre.

gpm. gallons per minute.

granular (G). a dry formulation of pesticides and other components in discrete, small particles, designed to be applied without a liquid carrier.

granule. see *granular.*

grass. referring to a monocotyledonous plant belonging to the grass family that has long, narrow leaves and jointed stems.

habitat. the place where plants or animals live and grow naturally.

herbaceous. a plant that usually has little or no woody tissue.

herbicide. a pesticide used to control weeds.

herbivorous. pertaining to organisms that feed on plants.

hibernation. the process of passing the winter in a resting or nonactive state.

hormone. a chemical produced in the cells of a plant or animal that produces changes in cells in another part of the organism's structure.

host. a plant or animal species that provides sustenance for another organism.

host resistance. the ability of a host plant or animal to ward off or resist attack by pests or to be able to tolerate damage caused by pests.

hybrid. in plants, the offspring resulting from the cross-breeding of two genetically different plants.

hydrolysis. a chemical process that involves incorporating a water molecule into a molecule of a different substance.

hydrophyte. an aquatic plant living on or in water.

hydrosoil. soil at the bottom of the body of water, often referred to as sediment.

importation. the act of bringing an organism from one place or country into another place or country.

indigenous. native; originating or occurring naturally in the place specified.

inflorescence. a cluster of flowers.

inhibit. to prevent something from happening, such as a biochemical reaction within the tissues of a plant or animal.

inhibition. the process of slowing or stopping plant growth with an herbicide.

integrated pest management (IPM). an ecological approach to pest management in which all available necessary techniques are consolidated into a unified program so that pest populations can be managed to avoid economic damage and minimize adverse effects.

invert emulsion. an emulsion in which water droplets are suspended in oil rather than the oil droplets suspended in water.

invertebrate. any animal having an external skeleton or shell, such as an insect, spider, mite, worm, nematode, snail, or slug.

knapsack sprayer. see *backpack sprayer.*

label. the information printed on or attached to the pesticide container.

LC_{50}. the concentration of a chemical in air (inhalation toxicity) or water (aquatic toxicity) that will destroy 50% of the organisms in a specific test situation.

LD_{50}. the dose of a chemical calculated to be lethal to 50% of the organisms in a specific test situation; expressed in weight of the chemical (mg) per unit of body weight (kg) of the test organism.

leaching. movement of a substance, such as a pesticide, downward or out of the soil as the result of water movement.

leaf. a lateral outgrowth from a stem that constitutes part of the foliage of a plant and functions primarily to manufacture food by photosynthesis.

life cycle. the progression of stages in the development of an organism.

littoral zone. the area from the shoreline of a lake or other body of water to the maximum water depth where plant growth occurs; divided into four transitional zones: eulittoral, upper littoral, middle littoral, and lower littoral.

macrophyte. any plant that is large enough to be seen without the aid of a microscope.

macroscopic. anything that is large enough to be seen without the aid of a microscope; opposite of *microscopic*.

marsh. a tract of wetland principally inhabited by emersed herbaceous vegetation.

material safety data sheet (MSDS). an information sheet provided by a pesticide manufacturer describing chemical qualities, hazards, safety precautions, and emergency procedures to be followed in case of a spill, fire, or other emergency.

mechanical control. a pest control that involves physically altering the environment by hand or machine, such as using a rake or weed harvester, or by dredging, draglining, or drawing down the water level.

metabolism. the chemical process that takes place in a living organism to utilize food and manage wastes, provide for growth and reproduction, and accomplish all other life functions.

microscopic plant. a plant that cannot be seen except with the aid of a microscope.

mode of action. the way a pesticide reacts within the tissues of a pest organism to destroy it or regulate its growth.

monitoring. the process of carefully observing the activities, growth, and development of pest organisms over a period of time, often utilizing very specific equipment or procedures.

monocot. see *monocotyledon.*

monocotyledon. a member of a group of herbaceous seed plants having an embryo with a single cotyledon and usually parallel-veined leaves. Monocots are usually narrow-leaved plants such as grasses, sedges, and rushes.

monoecious. having staminate (male) and pistillate (female) flowers on the same plant.

mycelium. the vegetative body of a fungus, consisting of a mass of slender filaments called hyphae (plural: *mycelia*).

natural enemy. predators, parasites, or pathogens that are beneficial because they attack and kill organisms that are considered to be pests.

necrosis. localized death of living tissue. On plants, the dead tissue has a dark brown discoloration.

nitrogen fixation. the transformation of atmospheric nitrogen into forms available to plants, accomplished largely by certain species of bacteria.

node. a knob or joint of a stem from which leaves, roots, shoots, or flowers may arise. Nodes contain one or more buds.

nonindigenous. a species that is not native to an ecosystem or to a geographical region, such as an exotic or transplanted aquatic weed.

nonselective. a pesticide that has an action against many species of pests rather than just a few.

nontarget organism. any plant, animal, or microorganism other than the intended target of a pesticide application.

nontoxic dye. a blue dye applied to the water that acts as a light screen, blocking light needed by submersed weeds for photosynthesis and growth.

nonvascular plant. a plant that does not contain specialized conducting tissue; used to describe the lower plants such as algae and mosses.

noxious weed. legal term for a specifically identified weed that is especially undesirable, troublesome, and difficult to control.

ocular. pertaining to the eye; one of the routes of entry of pesticides into the body.

oligotrophic. water that is lacking in nutrients.

opposite. describes leaves or bracts occurring two at a node on opposite sides of the stem.

oral. through the mouth; one of the routes of entry of pesticides into the body.

ornamental. cultivated plants that are grown for purposes other than food or fiber.

ovary. in flowers, the enlarged basal portion of the pistil that will become the fruit.

ovate. egg-shaped.

overwinter. to pass the winter; many plants and animals overwinter in a dormant stage.

palmate. when describing leaf veins, refers to several primary veins spreading out like the fingers of a hand.

panicle. a type of inflorescence composed of several *racemes*.

part per million (ppm). one part of a substance in one million parts of another substance, usually measured on a weight basis.

pathogen. a disease-producing organism.

peduncle. the stalk of a flower borne singly or the stalk of an inflorescence.

pellet (P). a pesticide formulation consisting of the dry active ingredient and inert materials pressed into uniform-sized granules.

percolation. the process by which water and dissolved materials flow downward through permeable soil.

perennial. a plant that lives longer than 2 years and usually flowers each year. Some may live indefinitely.

persistence. a measure of how long a pesticide remains in an active form at the site of application or in the environment.

persistent pesticide. a pesticide that remains active in the environment for long periods of time because it is not easily broken down by microorganisms or environmental factors.

pesticide. any substance or mixture of substances used to prevent, destroy, repel, kill, or mitigate any animal, plant, or plant disease considered to be a pest.

pesticide formulation. the pesticide as it comes from its original container, consisting of the active ingredient blended with carriers and adjuvants.

pesticide registration. the status given to a product to allow for its sale and use as a pesticide by the U.S. Environmental Protection Agency and the state where it is sold.

pesticide resistance. genetic ability of an organism to tolerate or detoxify a pesticide that once killed most individuals of the same species.

petiole. the slender stalk or stem of a leaf; also called a leaf stalk.

pH. a measure of the concentration of hydrogen ions in a solution. As the number of hydrogen ions increases, the solution becomes more acid.

phloem. the tissue in higher plants that transports organic nutrients manufactured in the leaves to other parts of the plant.

photic zone. that portion of a body of water where there is sufficient light for plant growth. The photic zone of most California lakes ranges from 10 to 12 feet.

photodecomposition. degradation of a pesticide by light.

photosynthesis. the process by which plants convert carbon dioxide and water into carbohydrates using sunlight as the energy source.

phreatophyte. a plant, such as saltcedar, with a very long, extensive root system that enables it to consume large quantities of water, often to the detriment of surrounding areas.

phytoplankton. plankton consisting of algae, and found floating in bodies of water.

phytotoxic. the ability of a material such as a pesticide or fertilizer to cause undesirable injury to plants.

piscicide. a pesticide used to kill or control fish populations.

pistil. the ovule-producing (female) part of the flower.

pistillate. referring to plants, flowers, or flower structures that contain the female pistils or seed-producing ovaries but are missing the stamens or have sterile stamens.

pith. the soft, spongy cellular tissue in the center of certain plant stems.

plankton. the passively floating and usually microscopic animal and plant life found in bodies of water.

planktonic alga. a single-celled and often microscopic alga that, in large numbers, can turn a body of water green or brown.

plant growth regulator (PGR). a pesticide used to regulate or alter the normal growth of plants or plant parts.

pond scum. a common name for the dense, free-floating mats of filamentous algae.

postemergent application. application of an herbicide after the target weeds have emerged.

potency. pertaining to the toxicity of a pesticide.

potentiation. an increase in the toxicity of a pesticide brought about by mixing it with another chemical such as another pesticide.

preemergent application. application of an herbicide before the target weeds emerge.

psi. pounds per square inch.

raceme. an inflorescence in which the main axis is elongated and flowers are born on pedicels (stalks) that are about equal in length.

rate. the amount of active ingredient of a pesticide product applied per unit area or other treatment unit.

residual pesticide. a pesticide that breaks down slowly and continues to be effective for an extended period after application.

residue. traces of pesticide that remain on treated surfaces after a period of time.

restricted-use pesticide. a pesticide, usually having the signal word *Danger* on its label, that can be used only by a certified applicator or under the supervision of a certified applicator.

restrictive statement. a statement on a pesticide label that restricts the use of that pesticide to specific areas or by designated individuals.

rhizome. an underground horizontal stem that usually contains stored food and numerous buds.

riparian. pertaining to the bank of a river, lake, or pond.

riprap. an aggregate of stones or chunks of broken concrete used to control erosion along the banks of waterways.

rodenticide. a pesticide used to control rats, mice, gophers, squirrels, and other rodents.

root. part of a plant, usually below the ground, that holds the plant in position, draws water and nutrients from the soil, and stores food.

rooted floating plant. an aquatic plant rooted in the sediment at water depths of roughly 1 to 5 feet.

rosette. a group of organs, such as leaves, clustered around a common point of attachment.

rpm. revolutions per minute.

rush. a grasslike plant, such as bulrush or horsetail, belonging to the rush family and characterized by round stems and small greenish flowers. Rushes typically grow in wet places.

saprophyte. an organism that obtains its nourishment from dead or decaying organic matter.

Secchi disk. a disk having alternating black and white quadrants used to measure water clarity by lowering it into the water attached to a calibrated rope or chain.

sedge. a grasslike, herbaceous plant that, unlike grasses, has unjointed, triangular stems.

sediment. soil at the bottom of a body of water.

seed. the structure of a flowering plant that contains the embryo. A seed will develop into a new plant under appropriate conditions.

selective pesticide. a pesticide that has a mode of action against only a single or small number of pest species.

signal word. the word *Danger, Warning*, or *Caution* that appears on a pesticide label that signifies how toxic the pesticide is and what toxicity category it belongs to.

site. the crop, animal, or area infested by a pest and to which a pesticide may be legally applied.

site of action. the location within the tissues of the target organism where a pesticide acts.

slurry. a watery mixture containing pesticide powder. Slurries leave thick coatings of pesticide residue on treated surfaces.

soil application. applying a pesticide to the soil surface rather than to vegetation.

soluble. a material that dissolves completely in a liquid.

soluble powder. a pesticide formulation in which the active ingredient and all inert ingredients completely dissolve in water to form a true solution.

solution. a homogeneous or single-phase mixture of two or more substances.

spike. an elongated inflorescence in which the individual flowers are borne tightly against the main stem.

spore. a small reproductive structure produced by lower plants such as ferns and algae.

spot treatment. a method of applying a pesticide in only a small, localized area where pests congregate rather than treating a larger, general area.

spray drift. see *drift*.

spreader. an adjuvant that lowers the surface tension of treated surfaces to enable the pesticide to be absorbed.

stamen. the pollen-producing (male) part of the flower.

staminate. referring to plants, flowers, or flower structures that contain the male stamens or pollen-producing organs but are missing the pistils or have sterile pistils.

static water. a pond, lake, or reservoir that has little or no inflow or outflow.

sticker. an adjuvant used to prevent pesticides from being washed or abraded off treated surfaces.

stolon. a trailing, aboveground runner or shoot that often roots at the nodes and forms new plants.

submersed. aquatic plants that live below the surface of the water. There are three subgroups of submersed plants: rooted, without floating leaves; rooted, with floating leaves; and without roots.

substrate. the bottom soil or other material in a body of water that supports aquatic plant roots.

surface active ingredient. see *surfactant*.

surface water. water found aboveground in ponds, lakes, reservoirs, canals, irrigation ditches, streams, and rivers.

surfactant. an adjuvant used to improve the ability of the pesticide to stick to and be absorbed by the target surface.

susceptibility. the sensitivity to or degree to which a pest is injured by a pesticide treatment.

suspension. fine particles of solid material distributed evenly throughout a liquid such as water or oil.

swath. the width of the area covered by one pass of the pesticide application equipment.

systemic. capable of moving throughout a plant or other organism, usually through the vascular system.

systemic pesticide. a chemical absorbed by and transported within a plant or animal.

tank mix. a mixture of two or more pesticides or other agricultural chemicals in the spray tank at the time of application.

terrestrial. relating to land as distinct from water or air.

thickener. an adjuvant that increases the viscosity of the spray solution so that larger droplets are formed by the nozzles.Thickeners are used to control drift.

tolerance. (1) capacity of a pest to withstand a pesticide treatment without marked deviation from normal growth or function; (2) the concentration of a pesticide residue that is legally allowed in or on agricultural products.

toxicant. a poisonous material.

toxicity. the potential a pesticide or other chemical has for causing harm.

toxin. a poisonous substance produced by a living organism. Some blue-green algae produce toxins that are harmful to livestock and other organisms.

trade name. a trademarked name given to a pesticide formulation by its manufacturer.

translocation. the internal movement of pesticides that are applied to: (1) plant foliage and are then absorbed and finally move downward through the *phloem* to underground plant parts; (2) the soil and are taken up by roots and carried through the *xylem* to the foliage or other parts of the plant.

tuber. a short, thickened, fleshy part of an underground stem. New plants develop from buds that grow in the axils of the minute scale leaves of a tuber.

turbid. a condition where a body of water is muddy or cloudy due to sediment being stirred up or suspended.

turion. a winter bud that forms in the leaf axils of certain aquatic plants. When a plant matures, turions may drop to the sediment and produce new plants.

umbel. a type of inflorescence in which all flower stalks arise from the same level.

vascular plants. plants having a vascular system composed of special cells that conduct water and nutrients.

vascular system. the conducting tissue of plants, composed principally of *xylem* and *phloem*.

vegetative. pertaining to plant parts or plant growth not involved in the production of seeds, such as roots, stems, and leaves

vegetative reproduction. production of new plants from vegetative plant parts such as roots, rhizomes, stolons, tubers, turions, cuttings, etc.

vertebrate. the group of animals that have an internal skeleton and segmented spine, such as fish, birds, reptiles, and mammals.

viscosity. a measure of the physical property of a fluid that affects its flowability. More viscous fluids are thicker, flow less easily, and produce larger spray droplets.

***Warning*.** the signal word used on labels of pesticides that have an oral LD_{50} between 50 and 500 mg/kg and a dermal LD_{50} between 200 to 2,000 mg/kg.

water-dispersible granule (WDG). a dry, granular formulation that will separate or disperse to form a suspension when added to water.

water-level manipulation. see *drawdown*.

watershed. The area that drains into a body of water, such as all upland areas, rivers, streams, springs, and groundwater contributing to a surface water supply.

water-soluble powder. a powdered pesticide formulation in which all components completely dissolve in water to become a true solution.

weed. a plant that interferes with the growing of crops or ornamental plants; endangers livestock; affects the health of people; interferes with the safety or use of roads, utilities, and waterways; or is a visual or physical nuisance.

wetland. an area of land that is periodically flooded by tides, rising rivers, rain, or human action. Wetlands include marshes, bogs, swamps, baylands, and riparian areas.

wettable powder (WP). a finely divided dry formulation that can be suspended in water.

wetting agent. an adjuvant used in pesticide mixtures to lower the surface tension of spray droplets, enabling them to come in close contact with, and spread out over, target surfaces, especially surfaces containing fine hairs or waxy layers.

whorl. three or more leaves arranged at the same level on a stem, typical of such plants as hydrilla.

woody. a term describing plant stems that consist mainly of hard, fibrous tissues.

work clothing. garments such as long-sleeved shirts, short-sleeved shirts, long pants, short pants, shoes, and socks. Work clothing is not considered personal protective equipment, although pesticide product labeling or regulations may require specific work clothing during some activities. Work clothing differs from and should not be confused with a coverall. While coveralls must be provided by the employer, work clothing can be required to be provided by the employee. Short-sleeved shirts and short pants are only considered acceptable work clothing under conditions expressly permitted by pesticide product labeling.

xeric. referring to an area that has dry or desertlike conditions.

xylem. the tissue in higher plants that transports water, dissolved salts, and materials such as pesticides from the roots to aerial portions of the plant.

zooplankton. plankton consisting of tiny single-celled and multicelled animals, and found floating in bodies of water.

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