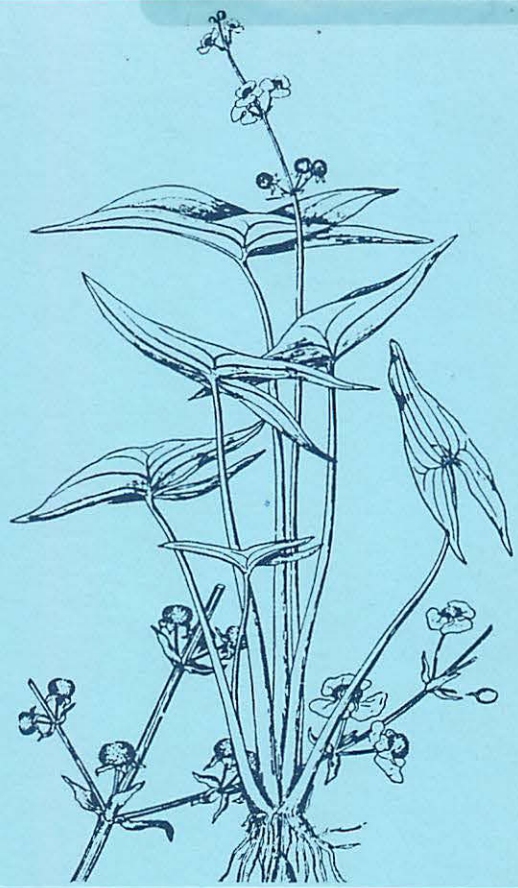
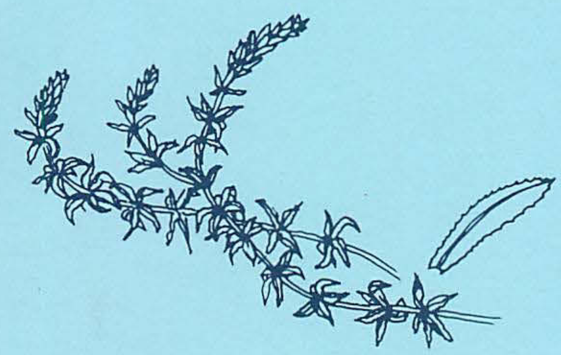
MARYLAND PESTICIDE APPLICATOR TRAINING SERIES





AQUATIC PEST CONTROL CATEGORY 5

MARYLAND COOPERATIVE EXTENSION
UNIVERSITY OF MARYLAND
COLLEGE PARK • EASTERN SHORE

MARYLAND PESTICIDE APPLICATOR TRAINING SERIES

AQUATIC PEST CONTROL

CATEGORY 5

A Training Program for the
Certification of Commercial Pesticide Applicators

Don Webster
Sea Grant Extension Program
Maryland Cooperative Extension

MARYLAND COOPERATIVE EXTENSION
UNIVERSITY OF MARYLAND
COLLEGE PARK • EASTERN SHORE

Produced with support from the Maryland Department of Agriculture by Maryland Sea Grant Extension, a joint program of the Maryland Sea Grant College and Maryland Cooperative Extension.

Maryland Sea Grant Publication Number
UM-SG-SGEP-2005-01

Acknowledgments

The author would like to thank Dr. Andrew Lazur, Dr. Reginal Harrell, and Ms. Jackie Takacs of the University of Maryland, and Mr. Ed Crow of the Maryland Department of Agriculture for their review of this publication. He also wishes to express his gratitude to Ms. Sandy Rodgers for her production assistance and to Ms. Nina Fisher for editing and formatting.

Products shown in this publication are provided for illustration and should not be construed as being recommended or endorsed by either the University of Maryland or the Maryland Department of Agriculture.

Funding for this publication was provided by the U.S. Environmental Protection Agency and the Maryland Department of Agriculture.

Credits

Photographs: pages 6, 7 and 37 by Don Meritt; pages 12 and 14 by Andrew Lazur; page 31 by Maryland Department of Natural Resources; pages 43, 44, 45, 46, 52 and 57 by Don Webster. Figures: 1-1 drawn by Nina Fisher; 1-2, 3-1, 8-4, 9-1 and 9-2 by Don Webster.

Plant drawings: page 14 (Duckweed) by Karen Teramura; page 15 (White Water Lily), (American Lotus Water Lily), page 16 (Coontail, Redhead Grass and Sago Pondweed) and page 17 (Water Milfoil) from *Chesapeake Bay, Nature of the Estuary: A Field Guide* by Christopher P. White with illustrations by Karen Teramura, published by Cornell Maritime Press, Inc.; page 15 (Watermeal), page 16 (Brazilian Elodea), page 17 (Slender Pondweed and Water Stargrass), page 20 (Common Reed), page 21 (Giant Cutgrass, Maidencane and Marsh Pennywort), page 22 (Pickerelweed, Sedges and Smartweed), page 23 (Soft rush, Spikerush and Water pennywort), page 24 (Bulrush) by the Information office of the University of Florida, IFAS Center for Aquatic Plants, Gainesville, 1990; page 17 (Water Starwort), page 18 (Bladderwort, Bushy Pondweed and Fanwort), page 19 (Curlyleaf Pondweed and Elodea), page 24 (Purple Loosestrife) by Rebecca Haefner, is reprinted, with permission, from *Water Plants for Missouri Ponds*, by James R. Whitley, Barbara Bassett, Joe G. Dillard and Rebecca A. Haefner, © Conservation Commission 1990, Missouri Department of Conservation, Jefferson City, Missouri; page 19 (Hydrilla), page 20 (Alligator Weed), page 24 (Creeping Waterprimrose) from Mississippi State University Cooperative Extension Service, Information Sheet 1034 (Hydrilla and Alligator Weed) and Information Sheet 1037 (Creeping Waterprimrose) with illustrations by Betty Mack Wilson; page 20 (Arrowheads), page 24 (Cattail) from *A Manual of Aquatic Plants*, by Norman C. Fassett (1969), The University of Wisconsin Press, Madison, Milwaukee and London; page 25 (Willow) by Christopher Newsholme (1992) from *Willows: The genus Salix.* Timber Press: Portland, Oregon and is printed with permission by B.T. Batsford Ltd, London, England.

For more information about this publication, contact:

Maryland Department of Agriculture
Pesticide Regulation Section
50 Harry S. Truman Parkway
Annapolis, Maryland 21401

Table of Contents

1

Why Control Plants?

Over 20,000 ponds now exist in Maryland. The increase during the past two decades has been rapid, with many ponds built to retain sediment and keep other potentially damaging runoff products from entering streams, rivers, and estuaries. These ponds were often built with state funding assistance and the associated increase has led to many requests for management assistance.

Solutions to problems in water bodies begins with design and continues through construction while also involving management of the watershed. To control problems, rather than just treat symptoms, the manager should identify the following factors:

- Nutrient inputs
- Water inputs
- Toxicants
- Aquatic vegetation
- Fish populations

Many ponds were built to control runoff into the Chesapeake and coastal bays in the Mid-Atlantic region. Engineers and developers often view impoundments as selling points for property and use them for landscaping and aesthetics as well as runoff control. Once communities become established, however, residents often fail to understand the need for pond management and frequently end up with poorly managed bodies of water that have chronic weed and water quality problems.

Ponds may look pleasing one year and become a nuisance the next if periodic management is lacking. Ponds without maintenance will often create problems for the owners, including growth of unattractive vegetation, unbalanced fish populations, fish kills, and high input of silt or other sediments that will ultimately fill a pond.

Plants in the Environment

Plants are a necessary part of the aquatic world. The benefits they provide to the environment include:

- Adding dissolved oxygen to the water
- Taking up nutrients
- Helping control turbidity
- Providing shade and keeping waters cooler
- Helping control shoreline erosion
- Providing habitat for fish and associated organisms
- Providing diversity to the aquatic ecosystem

But when systems become unbalanced, plants can take over the water body or unwanted plants invade, becoming aquatic pests or weeds. Plants that grow out of control can create dissolved oxygen problems by using this critical element during periods when light is limited. This oxygen usage can cause anoxia and result in fish kills and water quality problems. At the least, ponds become unsightly and may develop odors as plants decompose on the shoreline. Controlling weeds is necessary to bring the pond back into balance.

It is often a matter of opinion whether aquatic vegetation has become a weed. If the pond surface is covered by thick, dense mats of vegetation or if it is filled with a single type of vegetation, chances are good that the water body is out of balance and has a weed problem. When this occurs, a control program should be implemented to bring the pond into balance and prevent problems such as fish kills.

Properly managed ponds provide habitat for aquatic animals and cycle nutrients without becoming eutrophic. Ponds provide aesthetic value when incorporated into the landscaping of homes and developments. Deriving pleasure from water can take many forms. For that to occur, however, the intended uses of the pond must be known and the design should minimize both labor and costs in construction and management. A well-designed management plan will help achieve intended goals and objectives.

Factors Regulating Aquatic Plant Growth

Plants require several things to grow: light, oxygen, and nutrients (Figure 1-1). These factors need to be controlled to reduce aquatic weed problems. Designing ponds to minimize shallow areas keeps light from reaching areas where rooted aquatic plants can become a problem. Deepening existing ponds can prevent sunlight from reaching areas that have already become problematic. In summer, increases in phytoplankton can help block sunlight, shading bottom-dwelling plants and preventing their explosive growth. Other methods of shading include the use of dyes or colorants to decrease sunlight penetration, although these methods can elevate ammonia concentrations in aquaculture ponds by interfering with the ability of phytoplankton to absorb nitrogen.

Oxygen is affected by the growth of aquatic plant life (Figure 1-2). During the daytime, when sunlight is available, plants produce oxygen as a byproduct of photosynthesis. When the sun sets, or during cloudy weather, aquatic plants use oxygen through respiration, competing for it with other aquatic life. Ideally, a pond's oxygen production rate exceeds its respiration rate. In some cases, extreme growth of plant life can severely impact the oxygen in a pond. During hot, sunny, summer weather, ponds with aquatic plant problems can become

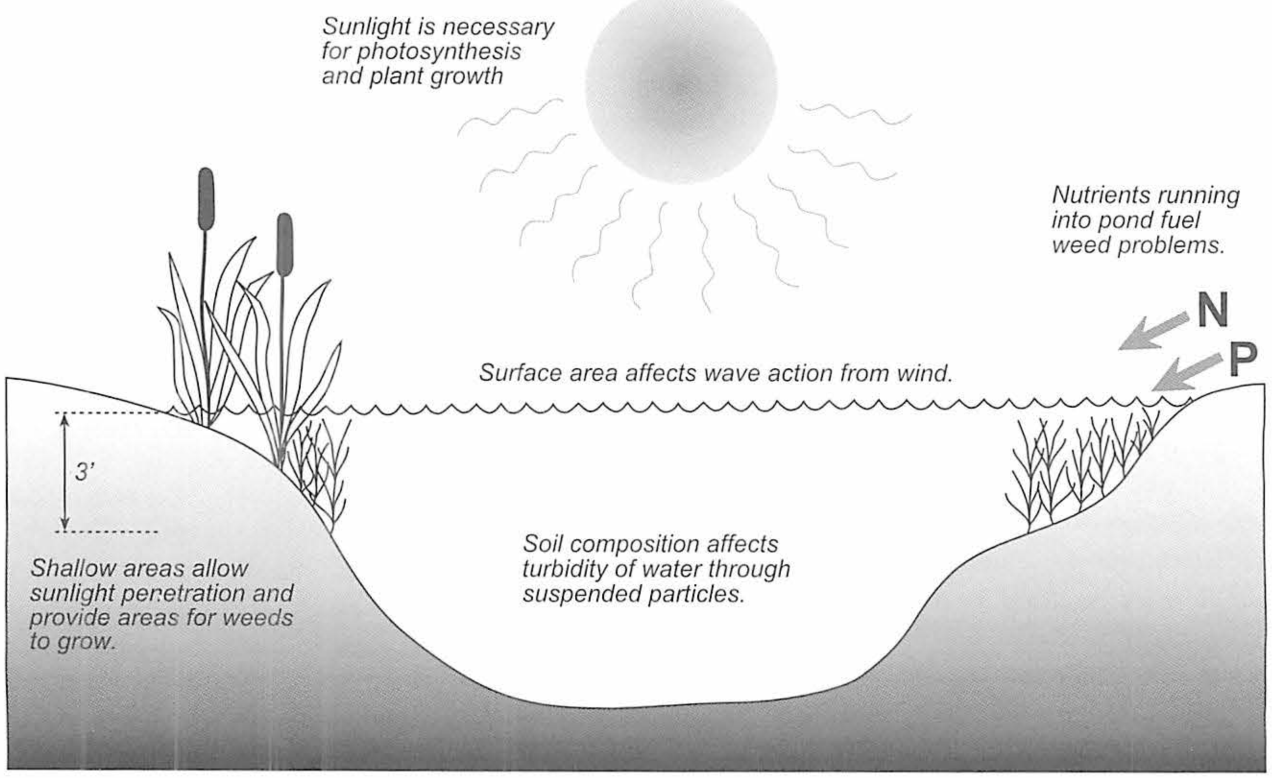


Figure 1-1. Sunlight, nutrients, and oxygen are all necessary for plant growth. Minimizing the amount of bottom area shallow enough for sunlight penetration and regulating the quantity of nutrients coming in to the pond can help reduce the ability of pond weeds to gain a foothold in the body of water.

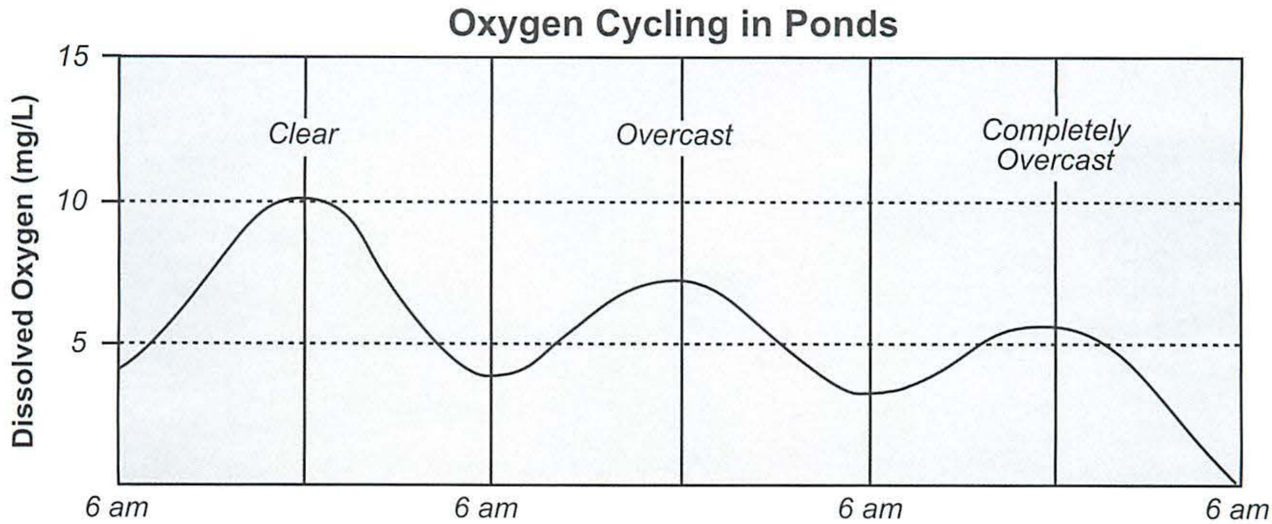


Figure 1-2. Dissolved oxygen (DO) levels in ponds vary throughout the day and nighttime. In general, DO rises during the day as plants produce oxygen through photosynthesis and declines after the sun goes down.

supersaturated with oxygen. In this case, the levels are above those normally present in saturated water and often a severe swing in the opposite direction takes place after sunset, with oxygen concentrations dropping quickly throughout the nighttime and often causing anoxia. Fish populations become stressed, reducing the effectiveness of their immune system. Even if the animals do not die from suffocation immediately, there is a strong likelihood of disease outbreak within a few days to a week that can leadto the death of many fish in the pond.

Nutrients are required for plant growth, but an oversupply can cause severe weed problems. Nitrogen and phosphorus are the nutrients most abundant and can be introduced into a pond from both point and non-point sources. A point source is a defined entryway, such as a pipe carrying human or animal waste. Non-point sources are broad areas that may drain into an impoundment, carrying wastes with the liquid.

In fresh water, phosphorus is the limiting factor in phytoplankton production and overnutrification can lead to the explosive growth of these and other plants. Nitrogen is also important and should not be overlooked when assessing potential pondweed problems. Nutrients may come from fertilizer runoff; wild or domestic animal wastes; forests, roadways, feed lots or fields; human sewage; failing septic systems; and many other sources. Waterfowl are a major source of nutrients in the Mid-Atlantic region, especially during winter when migratory geese and ducks are present in large numbers. Waterfowl can dump heavy nutrient loads into waterways, causing problems in the spring before the wastes decompose.

Review Questions

1. ***Which of the following is NOT a factor to consider when managing a pond?***
   - *a. Aquatic vegetation*
   - *b. Nutrient inputs*
   - *c. Altitude*
   - *d. Water flow*
2. ***On a sunny summer day DO levels:***
   - *a. Stay the same throughout the day and night*
   - *b. Rise during the daylight hours and decrease at night*
   - *c. Fall during daylight hours and rise at night*
   - *d. None of the above*
3. ***What is the most limiting nutrient for phytoplankton production in a freshwater system?***
   - *a. Iron*
   - *b. Phosphorus*
   - *c. Nitrogen*
   - *d. Magnesium*

2

Pond Design and Watershed Management

Aquatic plant control begins with the design phase of a pond project. Decisions about the intended use or uses of the pond may greatly affect future plant growth and potential problems. For example, many ponds in Maryland constructed since 1980 were built to trap soil and nutrients to prevent these substances from entering the Chesapeake Bay. Ponds designed for this function become shallower each year, making them more susceptible to weed problems over time. Also, many ponds are built to attract waterfowl for hunting or refuge. These birds add nutrients to the pond and bring in unwanted aquatic plants on their bodies. Once established, such plants can cause management problems, particularly during the summer.

Light penetration is a significant factor as well. Areas shallower than three feet frequently experience problems with aquatic weeds, as sunlight easily penetrates these depths and spurs plant growth. If shallows pose a problem when designing a pond, then the sides should be sloped as steeply as possible to reach depths over six feet to minimize the amount of shallow area. Soil types also play a role in maintaining proper slope without contributing to erosion from wind-driven waves.

The fate of chemical herbicides should be factored into pond design. Ponds with water flow will be harder to treat since many chemicals require some residency time to be effective. Downstream waters can determine whether chemicals can legally be used and affect the issuance of permits by state authorities. Even the use of dye colorants becomes more expensive with significant water flow through a pond.

Water control structures allow the manager to regulate a pond's water depth. Dams with boards or flashboard risers allow regulation of water depth so that herbicides stay in the system until they have completed a kill. These structures offer a way to flush floating weeds downstream during periods of high flow. They can also be used to draw down water levels to dessicate shallow vegetation, providing a cost-effective control measure.

Design Uses

The intended uses of the pond are important because they affect the final design and construction. Some uses are:

- Sediment/nutrient control and retention
- Beauty, landscaping, or aesthetics
- Firefighting
- Irrigation (field, orchard, lawn, golf course, etc.)
- Wildlife habitat or breeding
- Recreation (swimming, boating, picnicking, or other)
- Fish production (recreational or sport fishing, home food production or supplemental income, or commercial)

Each use requires a different design which should be carefully considered prior to construction.

Dam board riser systems such as this one allow regulation of water depth in ponds, a cost-effective measure for controlling pond weeds. These structures can lower water levels to dessicate shallow vegetation, for example, or raise levels during periods of high flow to float weeds downstream.

Multiple-use ponds require compromises in design and are not as efficient as a pond designed for a single use. For instance, ponds intended for firefighting or irrigation should be kept clear of aquatic weeds that could foul the pump intakes. Ponds designed for recreational fishing should include structure and aquatic plants to provide fish habitat. Golf course ponds may not be able to be treated with herbicides since these water bodies are often used for watering and the chemicals would harm greens and fairways.

The watershed should be developed to control high-velocity runoff that can erode slopes and carry sediment into the pond. Sediment loading muddies the water and can prevent some herbicides from working properly. Soil profiles of the construction site and the surrounding area should be identified and evaluated before design begins.

Consult with knowledgeable design engineers before construction. The Natural Resources Conservation Service (NRCS), located in most counties and listed under government agencies, is an excellent source of assistance. This organization has soil maps of the area and may have design, construction, and permit information on file.

Watershed Management

Management of the watershed will impact the pond. To assess a problem with aquatic weeds, it is necessary to inventory the surrounding areas. Treating a problem without establishing its cause will bring poor results that may require repeated treatment. Tracking down causes helps solve weed problems and can provide positive results in treatment.

Each water body has an associated watershed that captures the surface water running into it. In the case of a small pond in the middle of a field, this watershed may be small. The Chesapeake Bay watershed, however, comprises thousands of square miles, ranging over five states and the District of Columbia. As bay programs have shown, the watershed must be managed to solve the problems of the water body. Pond managers and aquatic applicators must also use this maxim. To inventory problems in a watershed, the investigator should establish its boundaries and record potential sources of problems.

- Use topographic maps of the area to determine how much land is in the watershed. Note thse slopes that will affect the speed of runoff and the source of potential sediment loads.
- Visit the site and log activities that could affect it. These include:
  - Streets, highways, or parking lots that drain into the pond, bringing in petroleum products as well as animal waste. Some drainage systems are designed to remove water as quickly as possible and flush large quantities of water and waste in a short time.
  - Farm fields or stockyards that may be a source of soil, fertilizers, chemicals, or farm animal waste to the pond.
  - Residential lawns undergoing fertilization or weed treatment. Residential use of fertilizers is a common source of nutrients since equipment may not be properly calibrated or application rates may be higher than necessary.
  - Construction sites losing large amounts of soil during rainstorms if not properly stabilized with approved sediment control structures.
- Look for control measures, such as grass buffer strips, surrounding the pond that filter soil, fertilizers, and other substances.
- Record uses of the pond such as swimming, irrigation, firefighting, fishing, or aquaculture, since these must be assessed during the process.

Ponds like this one have numerous uses in the watershed—as aquaculture impoundments, recreational fishing ponds and for use in controlling runoff of nutrients from livestock operations.

Consult the pond owners and inform them of potential problems due to sources identified. In older ponds that have shallowed through years of sedimentation, the long-term solution to aquatic weed problems may be renovation or reconstruction of the pond itself. This solution is expensive and time-consuming due to permit requirements and the equipment needed for the job. In large ponds or lakes, the cost may be significant and often exceeds the amount that individual property owners wish to share. Getting all owners in the watershed to understand that nutrient and sediment control remains critical to the long-term health of the water.

Review Questions

1. Most aquatic weed problems occur where light penetrates in less than:

a. 1 foot of water

b. 3 feet of water

c. 6 feet of water

d. 10 feet of water

2. What is a watershed?

a. A small building

b. The area that drains into the water body

c. The area that takes water away from a body of water

d. Pipelines for pumping water into a reservoir

3. Why should we be concerned with the runoff from surrounding areas draining into a pond?

a. Streets carry petroleum products and pet waste

b. Lawns can carry nutrients from fertilizer

c. Construction sites can shed large quantities of sediment

d. All of the above

3

Water Quality and Environmental Factors

Chemical and physical changes occur in ponds constantly. Many of these changes control which species of aquatic plants grow and the effectiveness of herbicides in treating them. Depending on water quality parameters, herbicides can also affect fish. Pond owners should consider both water quality and environmental factors, such as those described below, when choosing chemicals or when determining the methods and times for their use.

Water Quality

Temperature

Measuring the water temperature of a pond is important since most herbicides require temperatures above 60° F to work properly. Plants are more active when temperatures rise. If it is too cold, their metabolism is depressed and the herbicide will not reach the intended areas to effect a kill.

The oxygen in water at saturation varies inversely to the temperature. In summer, when temperatures may rise above 90° F, water holds less oxygen and may become quickly depleted. When the water becomes anoxic, fish die. Coldwater species, such as trout, require temperatures in the 52°– 68° F range while warmwater species, such as bass and catfish, can tolerate higher temperatures but do best within the mid-70° F to low-80° F range. Ponds often stratify in summer and winter, with water layers of different temperatures located at different levels. Water at the lowest level is almost always deficient in oxygen. Temperature is monitored with analog or digital thermometers.

Dissolved Oxygen

Dissolved oxygen (DO) is a critical parameter in the aquatic environment and should be monitored frequently in water used for fish production. Oxygen requirements of fish vary with the species and age of the animal, water temperature, and concentration of other substances in the water. Dissolved oxygen is dependent upon water temperature and factors such as salinity for its saturation point (Table 3.1). Concentrations of DO for warmwater fish should be kept above 5 mg/L (ppm) while coldwater fish require 6 mg/L.

Dissolved oxygen fluctuates both seasonally and daily. Oxygen becomes dissolved in water from air diffusion and as a product of photosynthesis of aquatic plants, especially planktonic algae. These plankton are the microscopic plants that give a pond its green color. During daylight, they manufacture oxygen that goes into solution in the water. On cloudy days and after the sun goes down, the process slows or ceases and the algae use the oxygen, driving down reserves. Levels of DO will, therefore, be highest at sunset and lowest at sunrise.

Dissolved oxygen is important in aquatic weed control because killing large quantities of aquatic plants uses up oxygen in decomposition. In summer, when DO levels are already low, this consumption may lower DO reserves to a level at which fish are unable to survive. Dissolved oxygen is measured with test kits and electronic meters but regular maintenance of the units is required to ensure accuracy.

Table 3-1. Relationship of temperature and dissolved oxygen in fresh water at sea level. Concentration is in parts per million or milligrams per liter.

Temperature		O_2 Conc.	Temperature		O_2 Conc.
°C	°F	(ppm)	°C	°F	(ppm)
0	32.0	14.6	21	69.8	9.0
1	33.8	14.2	22	71.6	8.8
2	35.6	13.8	23	73.4	8.7
3	37.4	13.5	24	75.2	8.5
4	39.2	13.1	25	77.0	8.4
5	41.0	12.8	26	78.8	8.2
6	42.8	12.5	27	80.6	8.1
7	44.6	12.2	28	82.4	7.9
8	46.4	11.9	29	84.2	7.8
9	48.2	11.6	30	86.0	7.6
10	50.0	11.3	31	87.8	7.5
11	51.8	11.1	32	89.6	7.4
12	53.6	10.8	33	91.4	7.3
13	55.4	10.6	34	93.2	7.2
14	57.2	10.4	35	95.0	7.1
15	59.0	10.2	36	96.8	7.0
16	60.8	10.0	37	98.6	6.8
17	62.6	9.8	38	100.4	6.7
18	64.4	9.5	39	102.2	6.6
19	66.2	9.4	40	104.0	6.5
20	68.0	9.2			

pH

The acid/base relationship in water is important for aquatic weed treatment. The pH is measured on a logarithmic scale from 1 to 14; 7 is the neutral point. Water with a pH less than 7 is acid and water with a pH greater than 7 is basic. Fish can usually tolerate pH fluctuations between 6.5 and 9, but may die if water drifts outside that range for very long (Figure 3-1). The pH, like dissolved oxygen, fluctuates daily due to the concentration of carbon dioxide in the water which, as carbonic acid, drives pH down during the night and up during the day. Fluctuations in pH can be minimized by increasing alkalinity since carbonates buffer the water. The pH is easily measured with inexpensive test kits, test strips, and meters, including a range of low-cost pocket testers.

Alkalinity

The measurement of carbonates in the water is important. Levels of 100 to 120 mg/L with pH values of 7.0 to 8.0 are optimal for supporting aquatic life. Alkalinity between 30 and 50 mg/L is adequate for most ponds; values above 40 mg/L are considered "hard." Applicators faced with water low in alkalinity (below 20 mg/L) should be cautious in applying copper compounds for aquatic weed control since they may prove toxic to fish. Alkalinity buffers water and prevents wide swings in pH. It can be increased by applying ground agricultural limestone to the pond, based on results of soil tests available from each county's Maryland Cooperative Extension office. Alkalinity is usually measured using chemical titration test kits.

Hardness

The amount of calcium, magnesium, and iron measured in water is termed "hardness." Hardness values of 20 to 300 mg/L are generally desirable, while those above 50 mg/L are considered "hard." Hardness is high in salt water due to its chemical composition. Soft water can increase the sensitivity of fish to toxic metals. Some herbicides are adversely affected by high hardness, causing them to become inactive or to precipitate out of solution. In cases in which high hardness is encountered, sprays should be mixed using distilled, de-ionized, or other treated water. Chemical test kits are available to measure hardness.

Carbon Dioxide

Carbon dioxide concentrations in water vary inversely with dissolved oxygen, with CO_2 levels falling during the day and increasing at night. While not usually important in the treatment of aquatic weeds, high levels can hinder oxygen uptake in fish. CO_2 can, however, have a positive effect by lowering pH and reducing ammonia toxicity. CO_2 is measured using test kits.

Ammonia

This key component of the nitrogen cycle can be toxic to fish under conditions of high pH and low DO. Ammonia decreases the ability of fish to take oxygen into the blood and can cause suffocation.

Levels as low as 0.06 mg/L can damage gills, reduce feeding activity, and impair natural functions. Most test kits measure total ammonia nitrogen (TAN); these values are then compared in tables against pH to calculate the percentage of un-ionized or free ammonia, which is detrimental to fish. Total ammonia nitrogen can be inexpensively measured with color comparator kits.

Nitrite

Nitrite is a form of nitrogen (NO_2) that is highly toxic to fish. If fish production is a consideration, nitrite levels should be monitored closely. Brown blood disease in catfish, for example, is caused by toxic levels of nitrites that prevent oxygen from being properly carried in the animal's blood. High nitrite levels can stimulate plankton growth, which consumes oxygen supplies and causes anoxia in a pond.

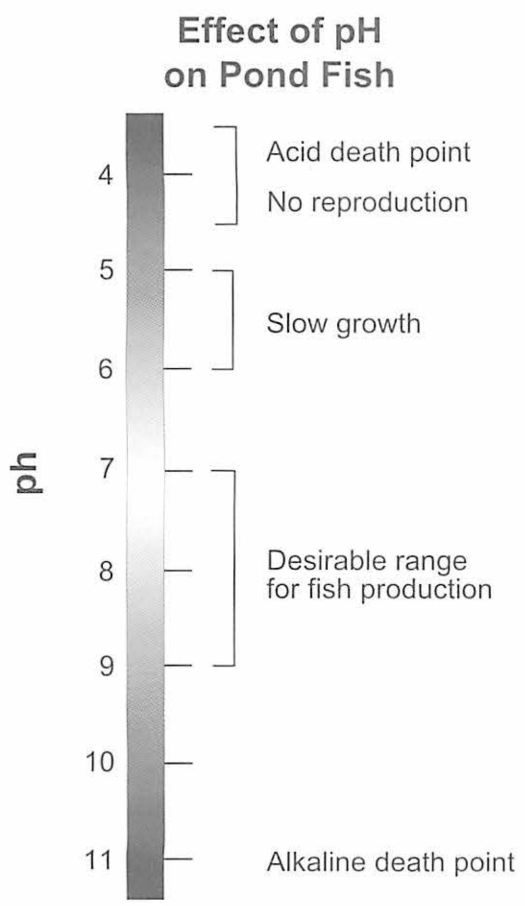


Figure 3-1. The pH of a pond can vary widely with levels from 7 to 9 desirable for fish production. Very low and very high levels can prove toxic to fish.

Phosphorus

Phosphorus is the limiting nutrient for phytoplankton production in freshwater ponds and must be controlled to manage plant growth effectively. It may enter the water bound to soil running off land or from animal feed lots, industrial operations, or sewage. Chemical test kits are available to measure phosphorus.

Turbidity

Particles suspended in water reduce light penetration and can interfere with the efficacy of herbicides. Such particles are usually composed of inorganic (clay and silt) and organic (planktonic algae and zooplankton) matter. Applicators need to assess the quantity of inorganic particles since some herbicides bind to these particles and can render the herbicides inactive. Diquat, for instance, should not be used in muddy water. When applying herbicides, applicators need to modify their methods to avoid stirring up mud or silt from the pond bottom and increasing turbidity.

The turbidity is measured using an electronic meter or with a Secchi disc—a black-and-white, multi-panel disk that is lowered into the water with a light rope. When the disk just disappears from sight, the length of rope below the water surface is noted.

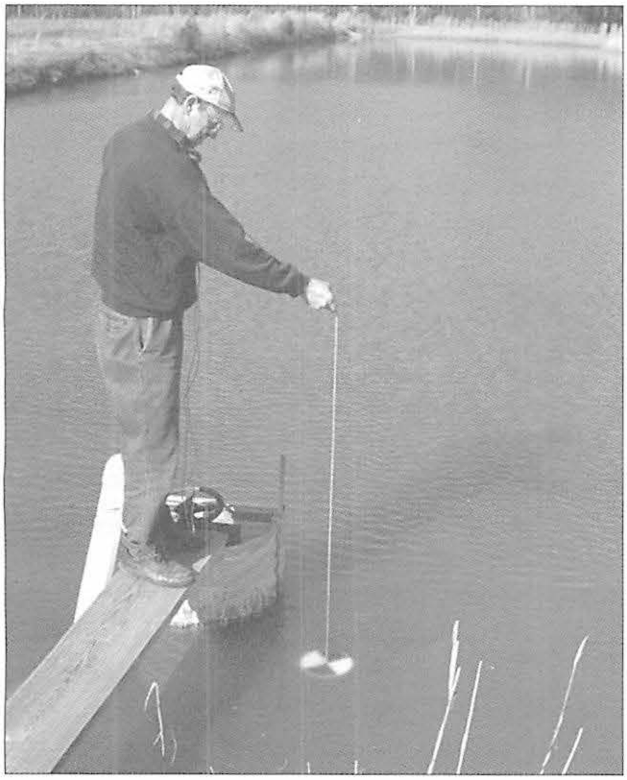
Environmental Factors

Successful aquatic weed applications can be affected by:

- Soil chemistry
- Water chemistry
- Weather conditions
- Water flow

Soil Chemistry

Generally, clay particles and organic matter in soils increase the tendency for herbicides to bind to the soils. This binding can render the herbicides somewhat ineffective and require the applicator to apply more herbicide. The applicator should consult the product label for recommendations on different soil types.


A Secchi disk is used to measure the clarity of water.

Water Chemistry

Becoming familiar with the parameters of water quality, their measurements, and their relationships is required for success as an applicator. Knowing the source of the water when tank-mixing herbicides is also important. Care should be taken to use clean water that is free of sediment. With hard water, the applicator shoud be prepared to obtain supplies that can provide the best mix for maximum effectiveness. Equipment should be well cleaned after application so that chemicals or poor water supplies do not remain in the tank.

Weather Conditions

Wind and rain are the most obvious weather factors to consider. Wind can affect application through drift, which causes poor coverage on target species while also possibly hitting non-target species. It can also cause rapid drying and reduce activity time for the herbicide. Strong winds can set up water currents that move herbicides applied below the surface from the target site.

Contact herbicides applied during rain are likely to be washed off the target surface, rendering application ineffective. This situation becomes particularly problematic with slowly absorbed systemic herbicides; contact herbicides may not be as readily affected. Large amounts of rainwater can enter a pond or lake, flushing the system and removing herbicide from the target area before it is effective. The applicator must be aware of the weather conditions and plan operations accordingly.

While weed treatment in static ponds or lakes can be relatively easy, flowing water makes the job more difficult. Submersed weeds must remain in contact with sufficient herbicide long enough to cause a kill. Flowing water carries herbicide away and makes it difficult to achieve this residency time. In these cases, other strategies must be evaluated, including use of multiple applications, herbicides with quicker absorption time, invert emulsions, subsurface hoses to get herbicide to the target area, and slow-release pellets formulated for flowing water.

Review Questions

1. ***Which is* not *a true statement about dissolved oxygen?***
   a. *Dissolved oxygen comes primarily from diffusion and photosynthesis*
   b. *Warm water contains more dissolved oxygen than cold water*
   c. *Fish need certain levels of dissolved oxygen to remain healthy and alive*
   d. *Dissolved oxygen can be measured with test kits and meters*
2. ***Which is* not *a true statement about pH?***
   a. *pH is a measure of the acid/base relationship in water*
   b. *pH can be measured with test kits, chemical strips, and meters*
   c. *A pH of 3.0 is healthy for fish*
   d. *pH fluctuations can be minimized by higher alkalinity*
3. ***Successful weed control applications can be affected by:***
   a. *Water chemistry*
   b. *Weather conditions*
   c. *Soil chemistry*
   d. *All of the above*

4

Identifying Aquatic Plants

To treat aquatic plant problems effectively, you must first identify the specific plant or plants requiring control. The science of identification is called taxonomy, which names and classifies organisms based on the way they are related. The key to controlling nuisance aquatic plants is to identify what must be controlled so that target measures can be assessed, evaluated, and instituted. It is necessary to identify non-target species for evaluating controls that inflict as little harm as possible.

Several aquatic plant types occur (Figure 4-1):

- Algae
- Floating
- Submerged
- Emergent
- Marginal

Algae

Algae are primitive plants that have no true stems, leaves, or root systems. They reproduce from fragmentation, cell division, or spores. These pose many of the pond weed problems in the region. Some algae produce toxins that can affect fish, wildlife, and even humans.

Planktonic Algae

Anabaena (blue-green), *Chlorella* (green), *Scenedesmus* (green)

Planktonic algae are microscopic plants suspended in water. These algae give ponds their traditional green color during summer and oxygenate the water. In ponds rich in nutrients, however, these plants may reach concentrations that cause eutrophication. Ponds with dense algal growth are

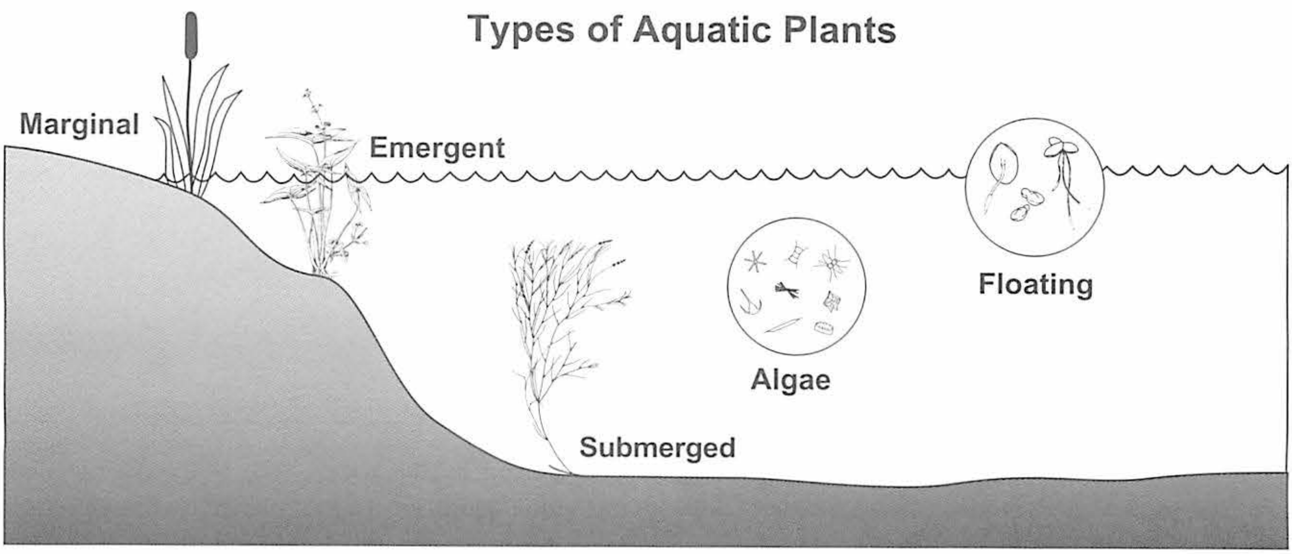


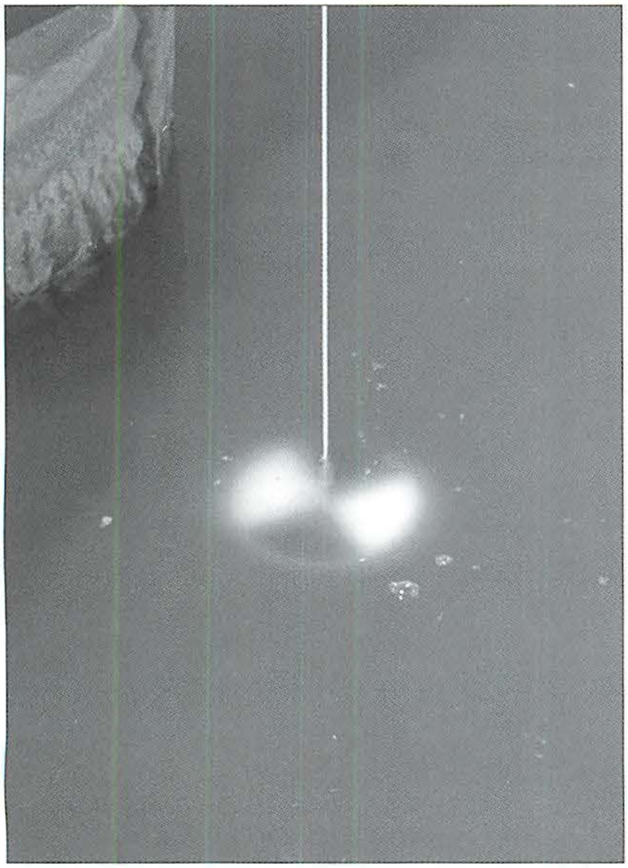
Figure 4-1. Many types of aquatic plants can be found in pond systems. Identifying them is one of the first steps in deciding which is the best way to control them.

experiencing a "bloom" resulting in dissolved oxygen problems shortly after. Blue-green algae pose problems in water used for public water supplies or aquaculture as they cause an off-flavor or undesirable taste (Figure 4-2).

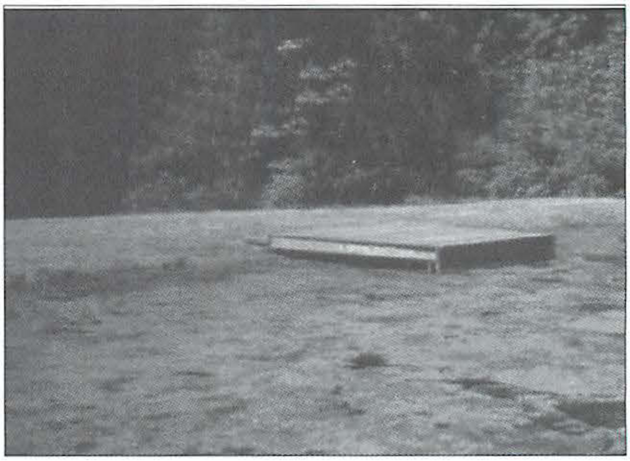
Filamentous algae

Pithophora (freshwater), *Hydrodictyon* (freshwater), *Entermorpha* (brackish)

Filamentous algae form dense mats on the surface of the water, usually beginning near shallow edges of a pond. These expand rapidly and in summer may turn black on top as older material dies and decomposes. Filamentous algae is sometimes referred to as "pond scum" or "pond moss" because of the way it looks. It is unpleasant to swim in and interferes with fishing due the mass of material in the pond. It can affect irrigation by clogging intake lines to pumps. The plant is actually a series of filaments that attach to the bottom or to structures.



Planktonic algae has become so dense in this pond that the Secchi disk begins to disappear just below the surface of the water.



Filamentous algae, which forms dense mats on the water surface, can affect irrigation by clogging intake lines to pumps.

Macro Algae

Chara spp.

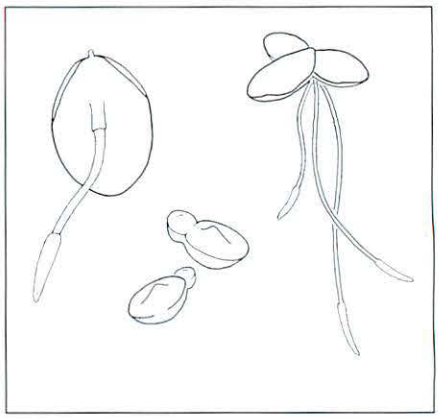
This genus includes macrophytic algae, such as *Chara* and *Nitella*. These plants may be mistaken for vascular plants since they have leaf-like structures. They often grow densely on the bottom, but are not rooted.

Floating plants have a true root-and-stem system. Their leaves float on the surface and may be rooted in the bottom or free-floating on the surface.

Floating Plants

Duckweed

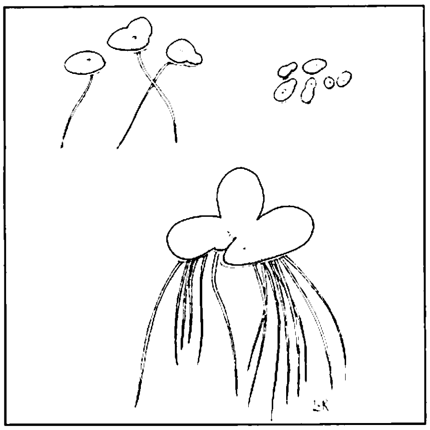
Lemna spp.



Common or little duckweed (*Lemna* spp.) is difficult to control due to its rapid growth and the fact that it is not rooted to the bottom but floats wherever moved by the wind. Each leaf constitutes an individual plant, with a root system underneath that takes up nutrients. The leaves are .08 to .16 inches long and .06 to .12 inches wide with a light green surface. Complete eradication is difficult because of the plant's small size and the ability of remnant plants to repopulate the water body by seed, budding, or fragmentation. Giant or greater duckweed is larger, with leaves .12 to .39 inches long and almost as broad, with dark green tops and purple-red bottoms. Reproduction of this species is usually by vegetative budding, but can occur by seed.

Watermeal

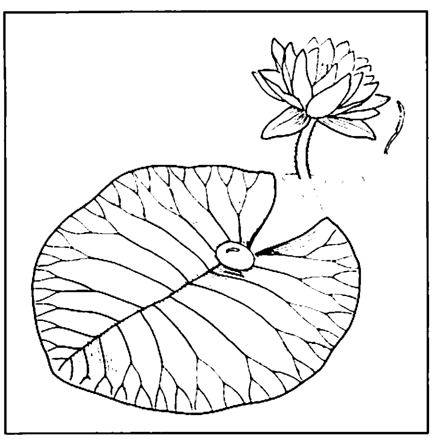
Wolffia spp.



Watermeal is the smallest flowering plant—so tiny (approximately 1/32 of an inch) that it is frequently mistaken for dust, seeds, or algae on a pond. Waterfowl that move between bodies of water frequently spread these plants on their bodies and feet. The plant is used as food by some water birds. Boats moved from infested water to non-infested water without proper wash-down can also spread the plant. Leaves rarely exceed .04 inches length, are green, and have a round or elliptical shape. Reproduction is usually from vegetative budding, but can occur by seed. Difficult to eradicate, these plants can lay dormant on quite dry soil along the shoreline and grow again when the pond fills with water.

White Water Lily

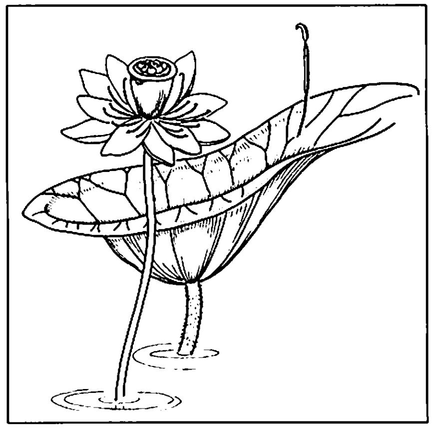
Nymphaea odorata



This ornamental plant can develop into a problem if left uncontrolled, as it will cover a pond's surface. It is usually found in muddy, shallow, stagnant, or slow-moving waters. Leaves are large (7 to 14 inches), green on top, purplish with numerous veins on the bottom, split in the middle, and centrally attached by the leaf stem or petiole. The plant produces fragrant, solitary white flowers that open only in daylight, usually in the morning. Reproduction is by vegetative branching from roots (rhizomes) or by seed, with 1-inch globe seeds ripening underwater.

American Lotus Water Lily

Nelumbo lutea



This attractive plant, like most water lilies, can grow so dense-ly that its leaves co-ver the entire surface of a pond. This lily is usually found in muddy, shallow, stagnant, or slow-moving waters. The leaves are circular and large (up to 23 inches in diameter), dark bluish-green, and not split in the middle. The center of the leaf can become depressed and form a bowl. The plant has pale yellow flowers 5 to 10 inches broad arising from a long stalk and presenting from July through September. Reproduction usually occurs during winter dormancy and is either by seed or by vegetative branching from tuber-forming rootstock rhizomes.

Submerged Plants

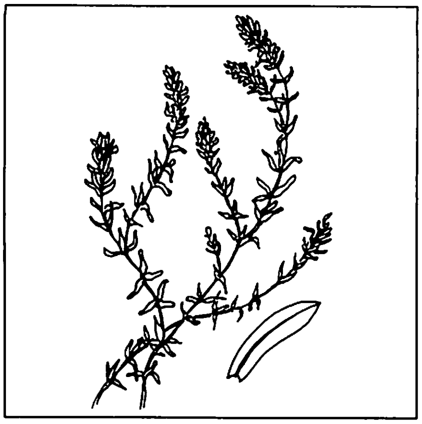
Submerged plants have true leaves and stems and root in the bottom sediment. These plants are widely distributed throughout this region. Often their flowers are seen on stems projecting above the water surface. When submerged plants become dense, they can prevent swimming and fishing.

Brazilian Elodea

Egeria densa

An exotic plant native to South America, Brazilian *Elodea* often roots in bottom mud in the quiet waters of ponds, lakes, and slow-moving streams.

Plants may grow 6 feet in height with branching at every double node on the stems; stands can become so abundant that they impede water use. The plant's leaves

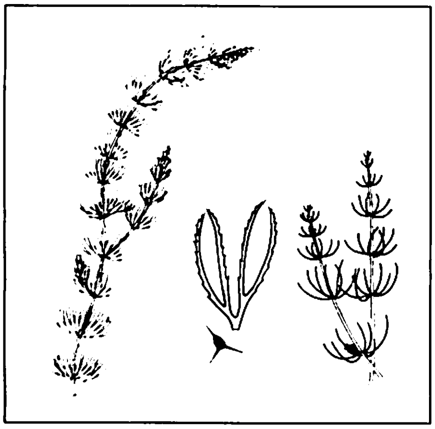


and its stems have some food value for waterfowl. Leaves are 1/5- to 1¼- inches long, in whorls of four to eight, with a distinct leafy appearance. The male flowers are large (½- to 1-inch wide) and occur from May through October. Reproduction is by fragmentation—only male plants have been found in the United States—and may account for the plant's rapid colonization of water bodies.

Coontail or Hornwort

Ceratophyllum spp.

A submerged plant found in the fresh water of quiet ponds, lakes, or slow-moving streams, coontail generally does not have roots and never grows

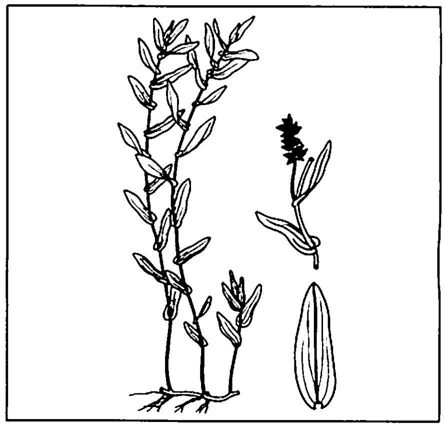


above water, even when flowering. Its stems may be partially found in bottom sediment, but roots are rarely present. It has some value as a wildlife food for muskrats and waterfowl and assists in pond aeration through photosynthesis. Coontail has thick bushy stem tips that resemble the tail of a raccoon and its elongated stems are branched with whorled, forked, or dark green leaves divided only once. Leaves can have a gritty feel since they are frequently coated with lime. The plant can grow up to 3½ feet tall and flowers are present from July to October. Reproduction is by seed or fragmentation.

Redhead Grass

Potamogeton perfoliatus

Found in fresh to moderately brackish water that is slow-moving or standing, this plant is not competitive when growing near other plants. It has sub-

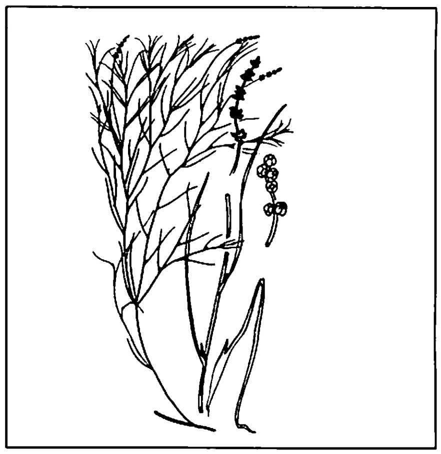


merged, alternate, thin, translucent, broad oval to lance-shaped leaves with 11 to 13 nerves in each and is rounded at the base. Redhead grass has whitish or pinkish rhizomes with flowers in bloom from June through September and spikes that are short cylinders with 2 to 8 whorls. The fruit is obviated, light brown or tan, and round on the back with a beak. Reproduction can occur from seed, rhizomes, or detached winter buds.

Sago Pondweed

Potamogeton pectinatus

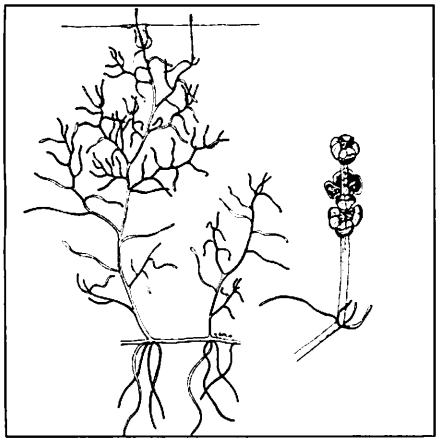
The sago pondweed is found in fresh to moderately brackish water that is slow-moving or standing and usually high in calcium. It is not competitive when in the



vicinity of other plants. The fruits, tubers, and roots are good sources of food for waterfowl. Leaves are wholly submerged, long, and slender (filiform), originating at the end of a sheath and tapering to a narrow point with 1 to 3 nerves and numerous strong cross-veins. The plant has a thickly matted rhizome system that can bear terminal tuberous bulbs. The spiky, greenish flowers with several unequally spaced whorls are present from June to September. The fruit is a plump nutlet and the beak is very short. Reproduction is by tubers, seed, or daughter plants arising from rhizomes.

Slender Pondweed

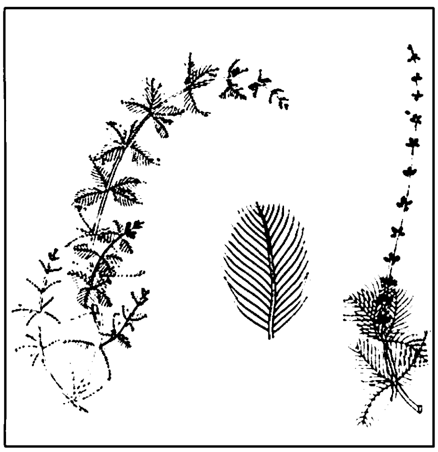
Potamogeton pusillus



This submersed perennial pondweed does not have either floating leaves or rhizomes. It occurs in water over 6 feet deep, often in association with other submergents such as *Hydrilla* and *Egeria*. It prefers water with high calcium content and can grow in fresh to slightly brackish water where waterfowl eat the seeds and foliage. Leaves are narrow, linear, grass-like, arranged alternately, and 1 to 2 inches in length with pointed tips. They may have a pair of small glands at the base and are free of stipules (paired structures found at leaf bases). Flowers occur in whorls of 3 to 5 and are 2 to 3 inches long, occurring underwater from July through September. Reproduction is by seed and stem sections.

Water Milfoil

Myriophyllum spp.



One of the most common submergent plants in Maryland, water milfoil grows in both freshwater ponds and on the brackish waters of the Chesapeake Bay. Muskrats and some waterfowl use the plant for food and many bird species eat its seeds. The plant can become extremely prolific, making boating, swimming, and fishing difficult to impossible. The leaves are featherlike, whorled, and limp. Leaves radiate from the stem and a root system is present. The plant's flowers are tiny and inconspicuous; they occur from July through September and are light yellow to brownish, surrounded by broad undissected axils (bracts) that occur in terminal spikes above the water surface. Reproduction is by seed, rhizomes, and plant fragmentation.

Water Stargrass

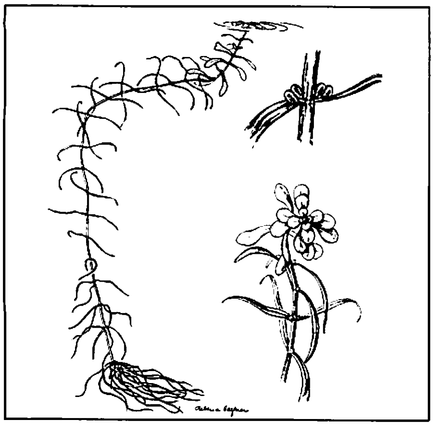
Heteranthera dubia

A perennial that is also known as mud plantain, this plant has small linear leaves that are 2 to 4 inches long and less than 3 inches wide. Water stargrass firmly roots in sediment and can develop into dense but patchy beds. It grows primarily in ponds, lakes, and slow-moving freshwater areas in clay or calcareous soils but is also found in stream beds. Its leaves do not possess a distinct mid-vein and the base of the leaf forms a sheath that wraps around the stem. The flower is yellow and solitary. It extends above the water surface, usually from early summer through September. The seeds overwinter on the pond or stream bottom and germinate the following spring. Reproduction can occur throughout the growing season by fragmentation.

Water Starwort

Callitriche spp.

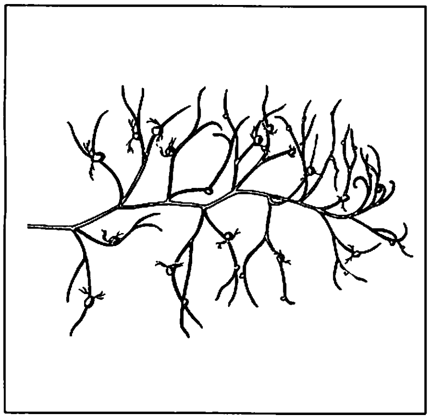
This starwort is a small plant that has bright green leaves and flowers from July to September. Fruits are found in pairs in the leaf axils and the flowers are small with up to three clustered together. Leaves are obovate. While classed as submerged, the leaves are often floating or emergent and can grow up to ¾ inches in length and from ⅛ to ⅓ inches in width. Seeds are numerous and set within the leaf axils. The plant occurs in static or slow-moving water such as ditches, streams, lakes and ponds, and swamps. This plant is an annual that reproduces from the numerous seeds it produces.



Bladderwort

Ultricularia spp.

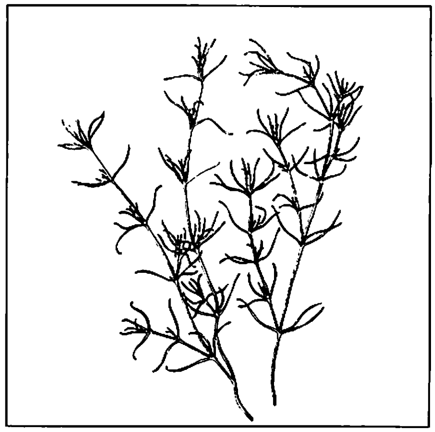
Bladderwort is an interesting plant that can be carnivorous—trapping insects, plankton, and fish larvae in small bladders or pouches for digestion. Found in acid or soft waters with mucky or sandy bottoms, this plant may form dense mats in shallow waters. It is of little use as food for wildlife. Submersed leaves are alternate and thread-like (filiform) and have bladders. Floating leaves occur in whorls of 4 to 10 and have inflated petioles. Roots are rare, but the plant can be anchored to the bottom of a pond or ditch. From May through early fall, 1 to 12 flowers appear at the end of a naked flowering stem without proper leaves. Reproduction occurs by seed or fragmentation.



Bushy Pondweed

Najas spp.

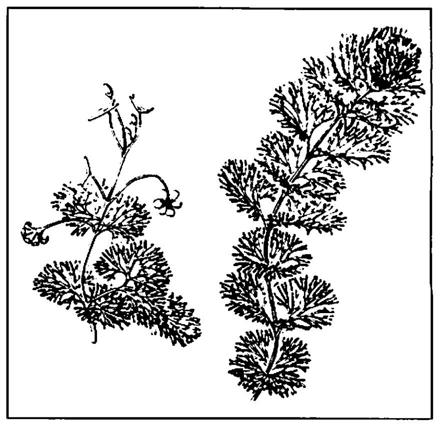
Four naiad species grow in Maryland: Southern naiad (*Najas guadalupenses*); *N. minor* which has no common name; Northern naiad (*N. flexilis*); and slender naiad (*N. gracillima*). These plants flourish in ponds, lakes, and sluggish freshwater to slightly brackish streams that are alkaline, although they tolerate a range of chemical and physical conditions. Naiads can become abundant, forming dense mats. Often associated with sandy bottoms, these plants can also grow in mud and provide excellent food for waterfowl. Plants are rooted and can grow up to 6 feet. The leaves are narrow (0.4 to 0.8 inches long and 0.02 to 0.03 inches wide, with fine spines), and found opposite each other or whorled in groups of three, with coloration ranging from olive green to reddish. Reproduction occurs by fragmentation or seed. Flowers are found in the leaf axils. The spines (serrations) on the leaf edges identify the individual species.



Fanwort

Cabomba caroliniana

This plant is a favorite of the aquarium industry, which may explain the extension of its range. Fanwort belongs to the water lily family, although it is classified as a submersed plant. It grows in quiet, slow-moving, acidic lakes and ponds with pH levels as low as 4. It usually roots in 3 to 10 feet of water. Fanwort is a perennial herb with well-developed roots and slender stems with two types of leaves. The submersed leaves are threadlike, opposite, or



whorled, usually green, and finely dissected in the shape of a fan. The plant's floating leaves are alternate, oblong or ovate in shape, constricted in the middle, and ¼ to ¾ inches long. Reproduction is by seed or fragmentation. Flowers are white or cream, consist of 3 sepals and 3 petals with a small yellow spot at the base, and usually appear between May and September.

Hydrilla

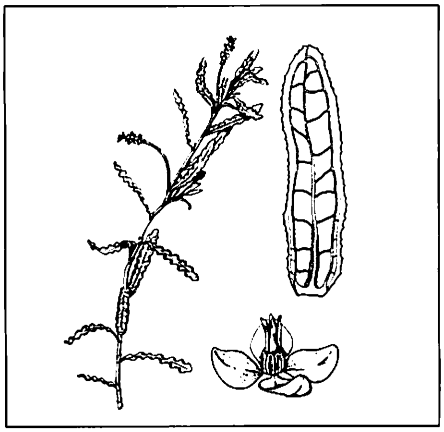
Hydrilla verticillata

Hydrilla is a non-native species that may have been introduced to the United States through the aquarium trade. It is a perennial herb that has slender, branching stems forming loose, frequently impenetrable mats. It is highly competitive with other plants and can grow in water as deep as 36 feet. It has minimal food value for most wildlife although it is eaten by coots and diving ducks. The plant occurs in freshwater lakes, rivers, and streams, but has been reported to live in waters up to 9 ppt salinity. It thrives under acidic or alkaline conditions. *Hydrilla* grows in muddy substrates and tolerates low light levels. While the plant may be confused with *Elodea*, *Hydrilla* has serrated leaves occurring in whorls of 3 to 5, with spines on the underside of the mid-rib, giving the plant a coarse texture. Reproduction occurs through fragmentation, seeds, rhizomes, turions, and tubers situated at the end of the rhizomes. Small white flowers form at the water surface in mid to late summer.

Curlyleaf Pondweed

Potamogeton crispus

An exotic plant thought to have been introduced from Europe in the 1800s, this plant gets its name from the obvious curls in the leaves. This pondweed prefers moderately moving fertile waters and silty-clay bottoms; it can be an indicator of pollution. The plant has either curly or undulating leaves with finely serrated leaf margins and is the only *Potamogeton* species without smooth margins. It has 3 to 5 distinct veins and a mid-rib. The stem is infrequently branched, flat, smooth, and submerged. The plant can grow almost 3 feet in length. It reproduces by seed and stem sections through vegetative reproduction that normally occurs in July. Burrs on the stem can remain dormant on the bottom for many months. Flowers occur as spikes on short petioles that extend to the water surface. Flowers blossom between April and June, with the plant usually dying back during the summer to remain dormant until fall when the vegetative buds germinate and the cycle restarts.



Elodea

Elodea canadensis

A native of North America, this plant is often confused with the Brazilian *Elodea*. This type of *Elodea* is a perennial that prefers very still and fresh to slightly brackish waters. The plant is a prolific oxygen producer and is used by many small fishes for protective habitat. It has moderate food value for ducks and coots. *Elodea* leaves occur in whorls of three and the lower leaves are opposite. It is a weakly

rooted plant that grows up to 10 feet in length. Flowers occur at the end of a single threadlike stalk and 2 to 4 flowers may cluster from a single stalk and appear from July through September. Reproduction occurs primarily through fragmentation.

Emergent Plants

Emergent plants exist both in and out of the water. They frequently line the edges of ponds and form dense clusters that can spread through rhizomes to include vast areas of the pond itself. If the pond is shallow, these plants may take over entirely. Roots and lower stems remain below the water suface , but upper stems and leaves protrude and can stay upright without the support of water. They may also be found in areas that contain saturated soils and do not require water to support themselves.

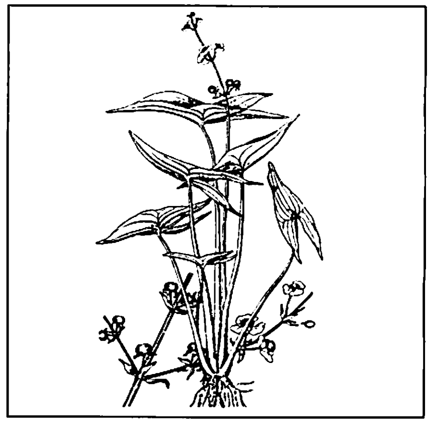
Alligator Weed

Alternanthera philoxeroides

This plant was introduced into the United States from South America and is now found in brackish and freshwater ponds. These plants often grow along a pond's banks in water less than 3 feet deep in conjunction with other species. Usually found in coastal areas, alligator weed grows best in fertile waters as mats extending from shore. The plant has little value for wildlife, although cattle and deer have grazed on it. A perennial, this plant has hollow stems that are simple or branched, glossy leaves that are opposite and lance-shaped with a distinct mid-rib that can extend up to 4 inches. Flowers bloom from May until October on long peduncles and consist of 6 to 20 white florets with 5 stamens on each head. Reproduction appears to occur by vegetative budding and, rarely, by seed.

Arrowheads

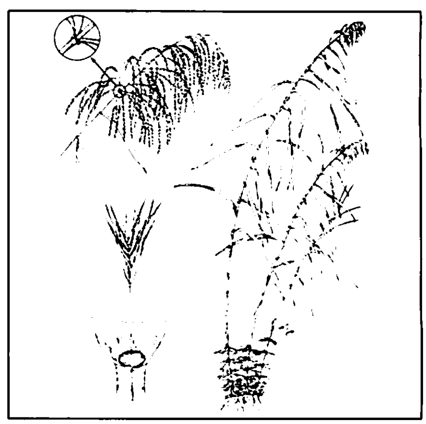
Sagittaria spp.



Two arrowhead species grow in Maryland—the coastal arrowhead (*Sagittaria graminea*) and the common arrowhead (*S. latifolia*). Both arrowheads are perennial herbs that emerge from the water and can reach 5 feet, with above-water leaves shaped like arrowheads. The coastal arrowhead often has underwater leaves, especially on young plants. Commonly found in shallow, fresh water that is slow-moving or static, these plants can also be found in low salinity waters along the shoreline of tidal creeks where they seem to stabilize the shoreline. Sometimes known as "duck-potato," they have considerable value for wildlife. Humans can also eat the tubers. The leaves are erect and lance-shaped, usually 2 to 5 inches long, and sharp-pointed. The plant rarely grows over 2 feet tall. White flowers are in 2 to 12 three-petal units, appearing from May through September. Reproduction occurs by seed and rhizomes and the plant overwinters from autumn-produced tubers.

Common Reed

Phragmites spp.



The common reed is a tall perennial grass that may grow 13 feet in height and is sometimes confused with the giant reed. This reed grows in swamps, marshes, and along the edges of ditches and canals in fresh or brackish water. It can establish itself in water several feet deep or on high ground through rhizome translocation. The plant provides roosting sites for birds and some cover value for other animals. It has a stiff, erect stem with flat, blue-green to green lance-shaped leaves up to 2 inches wide. Silky white hairs grow where leaf and sheath join. Plants bloom from midsummer into fall with flowers over 3 inches in length. Individual flowers, or spikelets, become more silver with age and are compressed with 5 to 8 flowers each. Reproduction occurs by seed and from thick, creeping rhizomes.

Giant Cutgrass or Water Millet

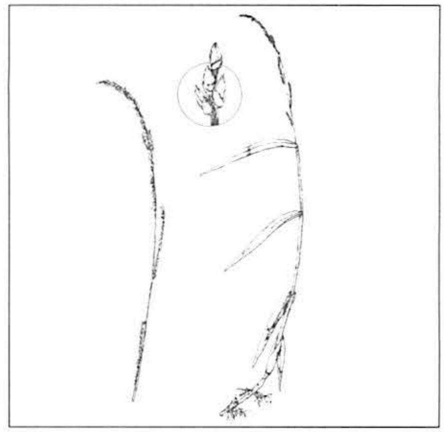
Zizaniopis milacea

This plant grows in shallow water, up to 3 feet deep, along the margins of ponds, streams, and marshes, usually in fresh water but occasionally occurring in brackish water marshes. It can grow as high as 10 feet and has large, rough-margined leaves up to 2 inches wide and 4 feet long. Giant cutgrass provides protection for nesting birds and other wildlife but has little nutritional value. It is a perennial grass with male and female flowers on the same plant. Its most prominent feature is the fine, sharply serrated leaf margin that faces upward with a prominent mid-rib. Rhizomes are large and scaly; stems are coarse, leafy, and unbranched. Rooting can occur in the lower nodes. The lower portions of the stem frequently reach 1 inch in diameter. It flowers from April through July and the fruit is a yellow inverse egg-shaped grain about .12 inches long. Reproduction takes place by seed or rhizomes.

Maidencane

Panicum hemitomon

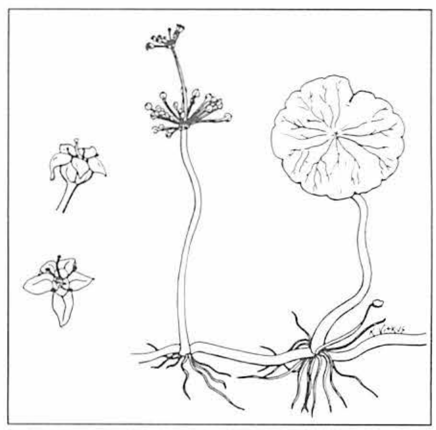
This plant has an extensive root-rhizome system and although it favors moist fields, it grows quite well in the dry soils of cultivated fields. Stems and



roots branch from the lower nodes. The plant generally grows up to 2 feet tall, but can reach 7 feet in height in deeper water. Leaf blades are rough to the touch along the margins. The leaves are from 6 to 11 inches long, ¼-inch wide at the base, and tapered to a point at the end. Maidencane has a one-sided panicle at the flowering portion of the plant and consists of ascending branches no more than ¼-inch wide and 1 to 5 inches long. Spikelets have both male and female parts, are lance-shaped, and extend about 1/10th inch. Flowers occur from May through August. Reproduction is by seed or through vegetative outgrowths from the rhizomes.

Marsh Pennywort

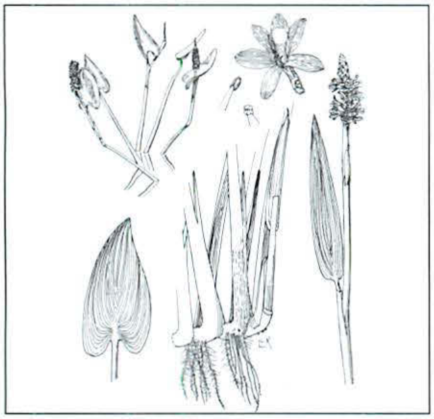
Hydrocotyle umbellata



Generally found in aquatic habitats in Maryland, these succulent perennials belong to the parsley family and are native to America. Although often rooted in the mud along pond and ditch banks, they can also grow while free floating. Large populations are common during the summer, growing either on the coastal plain or inland. Marsh pennywort has moderate value to wildlife as protective habitat but waterfowl often eat seeds and foliage. Stems run or lie on the ground and root at the nodes and the stems can thicken to ¼ inch in diameter. Leaf blades are light green, arise from the center of the stem, and are orbital in shape with scalloped edges. The petiole is no longer than 6 inches. Many small, white flowers bloom from April until September and the plants reproduce from seeds or fragmentation of the stems, where new leaves develop from the root nodes. The fruit is notched and about 1/8-inch wide.

Pickerelweed

Pondtederia cordata

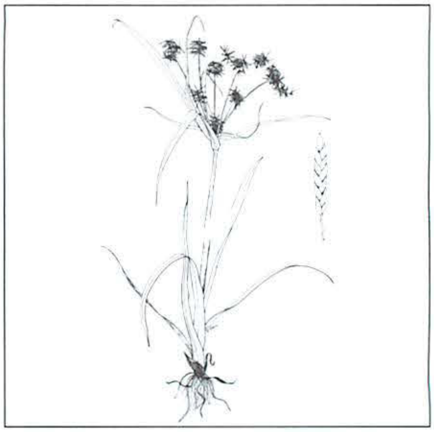


Pickerelweed is a perennial plant with thick, creeping rootstocks and erect leathery leaves that grow in clusters. Found along lake, pond, and stream margins in soft muddy bottoms, this plant grows up to 2 feet deep in a variety of water types, but often can exceed 3 feet. Leaves are 5 inches wide, twice as long as the width, and normally triangular-oval in shape. Flowers arise from a stem with one leaf and a terminal spike, which has numerous, showy, two-lipped flowers. The spike can grow 2 to 6 inches in length and the flowers bloom from April through October. They are irregular in shape and united at the bottom of the corolla to form a funnel-shaped tube. Fruits are 1/4-inch long and reddish. Reproduction occurs by seed and vegetative budding.

Sedges

Carex spp., *Cyperus spp.*

The sedges constitute one of the largest grass-like plant groups in the world with over 500 species in the United States. Most of these plants are perennials found in damp meadows, swamps, and fresh, brackish, and saltwater marshes. They have leafy stems ranging in height from a few inches to over 5 feet. Sedges have wildlife value, as birds eat the seeds and deer feed on the stems. In general, they are grass-like herbaceous plants that have solid triangular stems and alternate, three-ranked leaves. Each leaf consists of a blade and a closed sheath, or a bladeless closed sheath. Upright to dangling flower clusters that are yellow, brown, purple, or blackish grow toward the top. Most sedges have separate male and female flowers that are present from May through September. Reproduction is usually by seed.



Smartweed

Polygonum spp.

Although this group of plants occurs throughout freshwater areas of the country, only one species (*Polygonum amphibium*) is strictly aquatic. *Polygonum* species do well in moist soils and along water margins, such as ponds and ditch banks, as well as in cultivated fields during wet periods. They have upright, branched stems with lance-shaped or oval leaves, long-lasting flowers, and brown or black seeds. Smartweed provides an important food source for waterfowl, song, and upland birds; muskrats, nutria, and squirrels eat the seeds and plants. These plants are herbaceous annuals or perennials that will grow in waters up to 4 feet deep. Leaves are alternate with a sheath at the base, smooth or short-haired on the veins, and over 10 inches long. Stems are usually round and can branch upward as high as 8 feet in some species. Blooms are found on racemes. The flowers are pink, greenish, or white and occur from July through October. The fruit is a small, hard, dry seed or nutlet, dark brown to black, and up to 1/8 of an inch long.

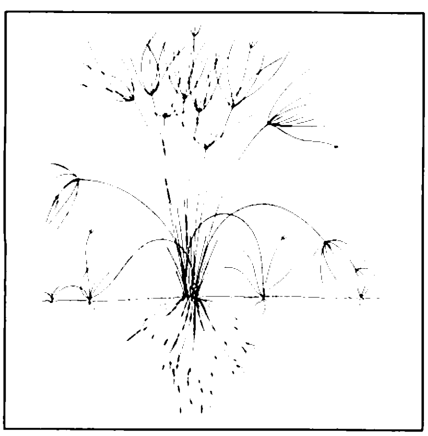
Soft Rush

Juncus effusus

A perennial clumping plant related to the lily, this rush resembles grasses and sedges. It is commonly found in large clumping stands along freshwater ponds and lakes and in low pasturelands in the eastern half of the United States and Europe. This plant grows equally well in wet or dry soils and can be from 18 inches to almost 6 feet in height. Waterfowl eat the seeds and deer sometimes eat the plant. Muskrats and nutria build nests within dense clumps. Soft rush has soft, pale-green, hollow, round stems that do not support leaf blades. The plant, however, does have chestnut-colored leaf sheaths of 2 to 6 inches long with a slender bristle at the end. Flowers cluster in units of 30 to 100, are about 1/10-inch long, and occur from June to September. Reproduction takes place either by vegetative clumping rhizomes or by seed.

Spikerush

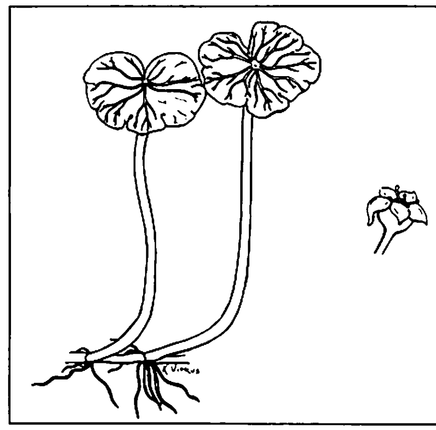
Eleocharis spp.



Although generally perennial, some species in this group are annual. These species normally grow in the mud along a pond or drainage canal bank or in the shallow waters of a pond or lake. Usually considered emergent, some species may spend their lives submersed in waters up to 6 feet deep. They are rapidly growing plants and are a pioneer group of species. Because of their fast growth, they are useful in erosion control and can proliferate in fresh and brackish water. Green leafless stems grow from a few inches tall up to 6 feet, occur in clumps, colonies, or mixed with other species, and are of moderate value to ducks. They arise from stolons or rhizomes, with stems that are three- or four-sided and can vary from as thick as a pencil to as thin as a thread. Flowers arrange in spirals, overlap, and occur in summer and early fall. Reproduction is both sexual and vegetative.

Water Pennywort

Hydrocotyle ranunculoides

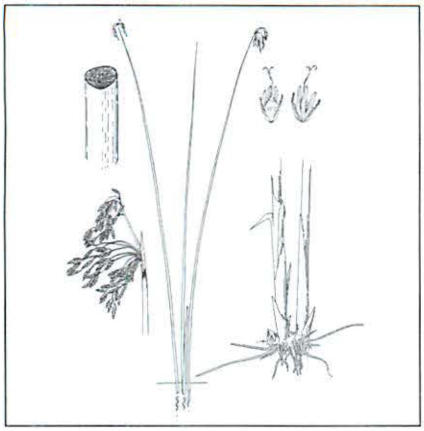


Water pennywort is a succulent perennial, a member of the parsley family, and an American native. Usually rooted in mud along ponds and ditch banks, this perennial can form dense mats that float on the surface. The plants can survive if they break and float free. Large populations of water pennywort grow in the fall, winter, and spring, but generally die back during summer. These plants have moderate value to wildlife, with seeds consumed by some waterfowl and the mass providing habitat for small animals. The stems grow up to 1/4 inch in diameter, run or lie on the ground, and root at the nodes even when floating. The leaf blades are dark green with a central reddish-purple spot at the point of attachment. Leaves are heart-shaped and alternate. Flowers are extant from April through July and consist of many small, white flowers arising from a central stalk. Reproduction is by seed or fragmentation of the stems where new leaves develop from the root nodes.

Bulrush

Scirpus spp.

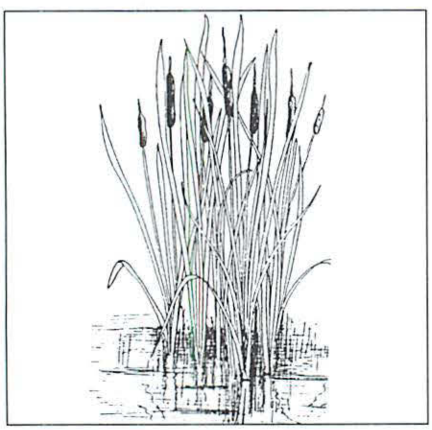
Although many varieties of *Scirpus* grow in Maryland, the most common is the great or soft-stem bulrush (*S. validus*). The *Scirpus* species are a group of annual and perennial wetland or aquatic plants that grow in clumps or over a large area of shallow water. They typically vary in size from a few inches to over 6 feet, growing in fresh as well as brackish water, and in soft mud or several feet of water along streams, ponds, and marshes. Often, several species will cohabit. They provide high-quality seed for waterfowl, songbirds, and marsh-dwelling birds; muskrats and geese feed on roots. Leaves have blades and sheaths on lower portions of the stem and leaf blades are flat and smooth. Bulrushes bloom from mid summer through mid fall with reproduction by seed and rhizomes.



Cattail

Typha spp.

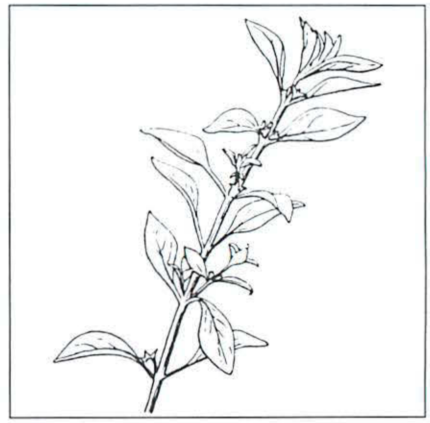
Four cattail species grow in North America, with all species occurring in wet or hydric soils. They inhabit marshes, swamps, and shallow waters, and can tolerate brackish water. Colonies can cover 10 to 12 feet in diameter. These plants have little food value for wildlife other than muskrats, nutria, and sometimes deer but the stands provide roosting areas. Humans can consume some parts of the plant. This group is typically recognized by the reddish-brown spines commonly seen in fall—female flowers that have developed into tightly bound seeds. Leaves are waxy, flat to slightly rounded, blue-green, and up to 10 feet in height. All cattail species have an extensive network of creeping rhizomes, which sometimes makes them difficult to control. Reproduction is by both seed and by rhizomes or fleshy rootstocks.



Creeping Waterprimrose

Jussiaea repens

While similar in appearance to alligator-weed, creeping waterprimrose grows along wet habitats, including ditch banks, lakes, and ponds, but is native to North America. It belongs to the primrose family and has some potential as a food source for crawfish, waterfowl, and songbirds. It is a perennial aquatic herb that often has reddish stems. These stems creep along the water's surface and are smooth or sparsely covered with hairs that can either float or root. While the plant grows on or near water banks, the creeping stems can reach 10 feet away. Leaves are simple, smooth, alternate, lance, or spatulate in shape, dark green, and from 1.5 to 3 inches long. Flowers bloom from June through October and are solitary and bright yellow. The petals are ½ to ¾ inches long, while the fruit is cylindrical in shape and about ⅛-inch long. Reproduction occurs by seed and rooted stem sections.



Purple Loosestrife

Lythrum salicaria

A hardy perennial with four-sided stems, purple loosestrife grows from 2 to 8 feet tall and dies back each year. It inhabits moist soils and shallow-water areas, such as lake and pond shorelines, stream banks, marshes, and ditches. Purple loosestrife has pink to reddish-purple flowers with yellow centers on long spikes that bloom from mid June into September. Leaves are linear, occur in opposite pairs that alternate down the stalk, and have tiny hairs. Leaves briefly turn red in the fall before fading and falling off. The plant's root system is extensive and creates a dense web that prevents other plants from becoming established. Reproduction occurs from seed; each mature plant can produce up to 2.5 million seeds annually, which are spread by wind, water, wildlife, and humans.

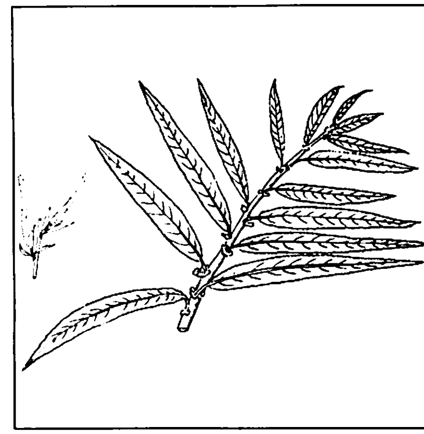
Marginal Plants

Marginal plants, including trees, line the edges of ponds. Their roots frequently use the water in the soil since they grow on the land surrounding the pond. Often, these plants become a nuisance because their roots can invade levees and dams, breaking them down and causing leakage. Their leaves also drop into ponds and decay, boosting nutrient levels.

Willow

Salix spp.

Willows are fast-growing, deciduous shrubs or trees and can reach 100 feet in height. Many pond owners grow them for their beauty and shade, but they can grow into dense thickets and their roots can interfere with bank maintenance due to their extensive root systems. Such systems can provide conduits for water, causing problems with seepage and, in extreme instances, levee failure. Willow bark has a high tannic acid content that can create water chemistry problems if large amounts of tannin enter the pond.



The leaves are lance-shaped and up to 6 inches long with finely-toothed margins. Male flowers are small growing on erect cylindrical catkins while female flowers are on small catkins that normally droop. The fruit is an oval, cone-shaped capsule about ½-inch long that contains numerous fine, hairy seeds by which the plant reproduces.

Review Questions

1. *Which of the following is NOT a type of aquatic plant?*

a. *Emergent*

b. *Terrestrial*

c. *Algae*

d. *Submerged*

2. *Which of the following is NOT a true statement about algae?*

a. *Algae have no true stems or leaves*

b. *Algae reproduce from fragmentation, cell division, or spores*

c. *Algae pose no problem for ponds at any density*

d. *Some algae can produce toxins*

3. *Which of the following is NOT a true statement about floating plants?*

a. *Floating plants have no true root or stem systems*

b. *Floating plants may be rooted in the bottom or float freely on the surface*

c. *Watermeal is the smallest flowering plant and is classified as floating*

d. *Water lillies belong to the floating plant category*

4. *Which of the following is NOT a true statement about submerged plants?*

a. *Submerged plants have true stems and leaves*

b. *The flowers of submerged plants are frequently seen above the surface of the water*

c. *Potomogetons, or pondweeds, are not part of the submerged classification*

d. *Submerged plants can cause pond problems when they reach high densities*

5. *Which of the following is NOT a true statement about emergent plants?*

a. *Emergent plants have true leaves and stems*

b. *Emergent plants do not have to be in water to support themselves*

c. *Emergent plants never spread through rhizomes*

d. *Emergent plants exist both in and out of water*

6. *Which of the following is NOT a true statement about marginal plants?*

a. *Some trees can be classed as marginal plants*

b. *Marginal plants line the edges of ponds*

c. *Marginal plants are never a problem if they are kept on levees or dams*

d. *Marginal plants can cause problems by losing leaves into ponds*

5

The Control Process

Assessment

Applicators should follow a logical process to control nuisance plants, minimize use of resources, and bring about long-lasting control. Protection of humans and the environment must be maintained. Following the steps below will prevent misuse of chemicals and the legal problems that can occur when such chemicals are not handled properly.

In assessing a body of water for control, the following steps should be taken (Appendix II has an aquatic weed analysis data sheet; Appendix III contains a permit application for the Maryland Department of the Environment: Request For Permission to use Toxic Materials for Aquatic Life Management Purposes):

• Accurately identify the plant(s) that require control and all other plants that live in the body of water, noting which require control and which are to be protected.

- Algae
- Floating
- Submerged
- Emergent
- Marginal

• Survey watershed and downstream areas to determine input and output locations of nutrients, chemicals, plant fragments, and any other substances that have potentially caused the problem and will be affected by the control process.

• Determine the best method of control for the target species.

- Mechanical
- Biological
- Chemical

• Determine the water usage (if chemical control is chosen) to determine restrictions and to minimize impact of the control program on unintended areas.

- Irrigation
- Drinking
- Swimming
- Livestock watering
- Fishing
- Aquaculture
- Other specified label restrictions

• Choose the proper herbicide.

- Labeled for aquatic use
- Adequate for the intended target(s)

• Obtain the proper permits.

- Maryland Department of the Environment (MDE)
- In some counties, the Natural Resources Conservation Service (NRCS) may issue permits for one-time emergency treatment

- Read and re-read the label.
  - Understand all information contained on the label
  - Labels may change so they need to be read whenever the herbicide is used

- Monitor water quality.
  - Some herbicides need particular conditions to work effectively
  - Water quality is crucial to proper pond health

- Determine the appropriate timing for application.
  - Seasonal considerations may include proper temperature ranges for response of the herbicide
  - Daylight timing considerations are necessary for herbicide action that requires sunlight

- Determine the area to be treated.
  - Partial treatment is best during warm months when massive die-offs of vegetation can cause anoxia which kills fish
  - Total treatment is generally prescribed during periods of cool water or when fish are not present

- Prepare the herbicide by mixing appropriate amounts of the formula for the target species.

- Apply the herbicide in a way that focuses on the target species.

- Keep all required records for the legally mandated period.

- Monitor the effectiveness for at least one week after application.

Review Questions

1. What is the first step that needs to be taken in controlling aquatic weeds?

a. Buy herbicide

b. Calculate the area to be treated

c. Identify the plant(s) needing control

d. Get a permit

2. Which Maryland agency issues permits for long-term control of aquatic weeds?

a. Department of Transportation

b. Department of the Environment

c. Department of Natural Resources

d. State Park Service

3. Why do you need to determine the water usage of a pond prior to choosing a herbicide?

a. To see if any restrictions exist for the potential herbicides being considered

b. To be able to choose the right herbicide for the job

c. To determine whether the uses will have to be restricted for some period of time

d. All of the above

6

Non-Chemical Control

In addition to chemical herbicides, other ways to control aquatic weeds exist. These methods may be quite cost-effective and yield good results. Prudent applicators choose the method that matches the job. The best control is being proactive and using management to eliminate factors that contribute to weed growth. For example, good sanitation practices within the watershed may prove helpful since many plants that become problem weeds are introduced from other locations. Careful attention to weed fragments clinging to boats, motors, and trailers should become standard practice. Controlling waterfowl populations and deterring them from using the waterway may be possible as well. Placing fish or vegetation in the pond, especially from aquaria, should be prohibited since many plants have become established and created problems due to this practice. If weed problems do develop, control should start early. The two primary ways to control weeds, in addition to chemical means, are mechanical and biological.

Mechanical Control

Mechanical control relies upon physically changing aspects of the water and weeds. Some of these measures are:

- Dewatering or controlling water levels
- Creating physical barriers to plant growth
- Shading water to retard sunlight penetration
- Pulling, cutting, or raking
- Dredging or reconfiguring the substrate

Dewatering

Dewatering is an old technique used effectively in many situations. It lowers the water level, exposing plants and roots growing in shallow areas to desiccation during the summer or freezing during the winter. Often effective on filamentous algae and some submerged plants, this technique does not work well in controlling marginal plants such as cattails or *Phragmites* since their roots extend several feet below ground. When used in summer, care must be taken that decomposing vegetation does not cause the water to become anoxic upon refilling the pond. This technique should also not be used if the water supply is insufficient to refill the pond. Control structures are required for this method; those with boards or valves are the easiest to operate to obtain the desired water level.

Physical Barriers

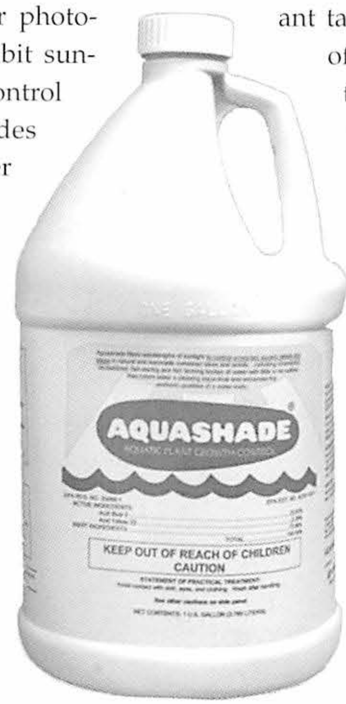
Introducing physical barriers in places where plants grow can control many submerged and emergent plants. Barriers include black plastic mulch or other engineered fabrics and full pond liners, although liners are expensive and must be cleaned so that sediment does not build up and allow re-establishment of vegetation.

Temporary barriers can be placed where needed for some time period and then moved after the intended effect occurs. This method is of moderate expense, especially if the water body is small or the area requiring treatment is limited in size. It is less labor intensive than physical removal of plants, which needs to be carried out frequently during the growing season. Solid plastic sheeting must have holes punched at intervals to allow gases generated in bottom sediment to vent. Without holes, the plastic will rise as gases build up underneath.

Engineered fabrics, or geotextiles, can prove useful. These fabrics come in many thicknesses, weights, sizes, and weaves. Construction supply houses can supply these along with data on the strength, weight, and transmissivity of the textiles. In places with excess sediment, enough can accumulate on the cloth for aquatic plants to gain a foothold. Careful assessment of the intended use and the area should be considered, along with monitoring, to gauge the effectiveness of the application.

Shading

Since plants require sunlight for photosynthesis, shading the water to inhibit sunlight penetration is an accepted control technique. Shading often includes adding strong blue dyes to the water (e.g., Aquashade®, Blue Vail®). These dyes are more successful in water over 3 feet deep, but should not be used in flowing water since the dye will quickly be washed away, rendering it ineffective and adding to control costs. While these substances are non-toxic, certain brands have been approved for use in raising fish for human consumption while others have not. Those approved for food-fish use are more expensive; applicators should ensure that dyes used are approved prior to their application. One caution in using dyes is that they can interfere with the nitrogen absorption capability of plankton and create elevated ammonia concentrations, especially in aquaculture ponds with daily feeding.



A longtime control method has been treating the water with fertilizer to encourage the growth of phytoplankton, the plants that give water its green color in the summer. A phytoplankton bloom of sufficient density may prevent sunlight from reaching the bottom, keeping rooted plants from gaining a foothold. Blooms provide the same type of control as dye colorants. A fertilizer schedule for this method begins in the spring and continues weekly or bi-weekly, depending upon need, until fall. Some modern inorganic fertilizers have time-release properties allowing a single application during the season to provide adequate nutrients throughout the summer. This method lowers the labor cost of repeat treatments, but must be used with extreme caution. It should never be used in a pond with an existing aquatic weed problem as it will likely aggravate the situation. It should never be used in water flowing through an impoundment or the fertilizer will be lost or diluted before becoming effective.

Pulling, Cutting, or Raking

Controlling plants by hand is a hard, unpleasant task. Aquatic plants are comprised largely of water, making the plants heavy due to the water in and on them. Water can make up to 90 percent of the total weight of product removed, adding to the cost of hauling harvested weeds away for disposal. Physical removal is a successful way to remove nutrients from the pond, however, preventing them from being recycled through uptake, growth, death, decomposition, and release. Scientists and managers have debated whether this benefit is offset by the cost of the removal. The method has little negative impact other than being labor intensive. It may leave fragments behind; since some plants reproduce by fragmentation, this method may move problem weeds to areas where they had not previously grown.

There are other ways to physically remove nuisance plants. Landscape rakes with wide, lightweight aluminum heads are useful. Hand cutters are thrown and retrieved, slicing the plants near their roots. Powered string cutters may be used for plants in marginal areas of the pond.

Another physical removal method is cheap and effective on floating plants, such as duckweed and watermeal, in ponds with a dam and board control system. When these plants are blown against the dam structure by the wind, pulling out one or two boards causes water to flow out quickly while carrying many weeds with it. This method is not useable in ponds without these types of structures.

For larger removal problems, effective mechanical equipment exists. Several companies specialize in floating cutters; public agencies often use these to control emergent plants that are clogging navigational waterways and interfering with boat traffic.

Cutter harvesters were used as long ago as 1900, when the U.S. Army Corps of Engineers controlled water hyacinths. Today, many state and federal agencies use these machines to keep waterways open. In Maryland, workers control *Hydrilla* in brackish waters with mechanical harvesters, especially in channels approaching marinas and freshwater lakes. Some machines can cut to depths of 10 feet using cutters that may spread over 15 feet wide. They can haul up to 15 tons of plant material at one time, with some designed to move cut plants to a transport barge for onshore removal while the cutter continues working. Removing plant material from the water is important so that it does not decompose, cause anoxia, and result in fish kills or offensive odors.

Today, harvesters on the market range from small electrical-powered units that can be fitted on small boats to specially designed units capable of harvesting and hauling tons of vegetation. The method remains slow and expensive, however, and cannot be used in areas where stumps or other obstructions exist.

Flail choppers have a rotating cylinder with hinged knife blades. The top of the unit is protected by a hood directing cut material downward. The unit is mounted on a hydraulic arm moved by the operator and the unit may be mounted either on land or on water-based equipment. Knife blades on the rotating cylinder chop the plants to small pieces, which destroys the tissue. Plant material is not usually removed but left to decompose, which can cause anoxia. Also, plant pieces and fragments may drift to other areas and colonize.

Cookie cutters consist of a barge-mounted cutting system that is useful in opening areas through large masses of floating vegetation or in breaking into shoreline and wetlands. It uses 6-foot diameter blades that spin on the front of the unit, cutting plants in their path and throwing material to the side. The blades provide propulsion through the

Cutter harvesters such as this one can cut and haul up to 15 tons of plant material at one time. Smaller units can be fitted onto boats for use in water bodies of more limited size.

water, driven by diesel-powered hydraulic components. The unit can also move sediment and cut into wetland soils to open channels or canals.

Some drawbacks do exist, however. One is that the unit causes plant fragments to be widely scattered and move plants to other areas. The blades also may cause sediment suspension, which could potentially cause environmental problems through the release of nutrients.

Rotovation was developed in Canada where chemical control has not been allowed. The machine is designed as an underwater rototiller with blades that penetrate the bottom, turning over the soil, chopping up plants, and releasing the roots. The unit is mounted on a hydraulic arm for positioning and is capable of reaching onshore and aquatic areas. The unit is operated in a crosshatch pattern that removes the root system below the sediment layer, providing long-term control of weeds.

Care needs to be taken when operating these machines in areas where obstacles such as tree stumps and rocks exist. Sediment is also disturbed during the process, so the equipment should not be used in areas where danger of releasing nutrients or contaminants into the water exists. As with most mechanical processes, picking up and removing plant material that has been broken up by the unit is necessary or the decomposition could cause environmental problems.

Dredging or Reconfiguration

Dredging deepesn shallow areas and removes accumulated nutrient-rich sediment. It is expensive and long waits for permits frequently occur. It also involves engineering and equipment costs and may create problems, such as where to place removed spoils. At times, however, this method is the only practicable solution to a severe weed problem.

An older pond with sediment accumulated over several years is one such example. Nutrients attached to these sediments accumulate as sedimentation lowers the water depth. Plants become established and have ready access to the nutrients they need to grow, while the water body's shallowness places them in the zone where sunlight allows them to grow in profusion. Often, these ponds have large numbers of waterfowl around and on them, increasing nutrient loads and fueling severe aquatic weed problems. Lakes and ponds such as this require frequent treatment to contain the weeds. Removing the accumulated sediment, while a good long-term solution, is expensive and should not be entered into lightly. For the best information on renovation or reconstruction of lakes and ponds, as well as the permits necessary to carry this method out, contact the Natural Resources Conservation Service (NRCS) in your county.

Biological Control

Biological methods of controlling aquatic weeds continue to draw interest from researchers and regulatory agencies. Many of these methods rely on manipulating the environment and are organically based. Biological control often uses the intentional introduction of predators, parasites, or pathogenic microorganisms into a population to reduce or suppress unwanted plants.

This type of control was practiced by ancient civilizations; they would introduce animals or plants to control others. An advantage of this control is that it tends to become long term because once the control agents are established, it may not be necessary to continue adding more. This method frequently involves the introduction of plants that can outcompete nuisance species. An important consideration, however, is whether the introduction is legal, or even wise. Such a control should never be attempted without professional advice and assurance that the introduction is legal.

Insects used as biological control agents can be classified according to their feeding preferences. Among the most usual are those that feed: externally by removing plant tissues; internally by removing plant tissues; and externally by removing internal plant fluids using sucking mouthparts. Some biological control specialists will use animals with several of these preferences during different life stages. For instance, they may use one during its larval period and another during its adult phase.

Herbivorous Fish

This method uses the release of biological control agents to target specific weeds at planned times. The most common method uses herbivorous fish to consume vegetation. Research has identified the types of vegetation that different herbivore species prefer. Like the previous method, care should be taken that the released animals are legal in both the state and the water body since some species carry heavy legal penalties for use in non-approved situations.

The species used most often herbivorous fish control is the triploid grass carp. This species is produced in hatcheries using methods that render the fish sterile and incapable of reproduction. These fish are very effective against submersed plants but will consume other types as well. At present, importing or possessing grass carp is illegal in Maryland. Purchase of the animals elsewhere, with transportation into the state and introduction into state waters will render the transporter in violation of federal and local laws. Other states in the Mid-Atlantic region do allow the use of triploid grass carp under permit from their natural resource or fish and wildlife agencies. Potential users should always seek advice from these departments before using these fish.

Other varieties of carp, especially those found within state borders, are legal but their use is neither wise nor effective. The introduction of carp into a pond should be avoided, especially where clay or silt make up the bottom sediment. The rooting action of bottom-feeding carp can stir up sediment, causing severe turbidity. Although this turbidity may prevent sunlight from reaching the bottom and limit plant growth, the muddy water is not attractive and may cause other water quality problems.

Insects

The U.S. Department of Agriculture and other agencies have worked with insect control technology since the 1950s. Some current plant species approved in 11 states for the use of insect control are: alligatorweed, waterlettuce, *Hydrilla*, and waterhyacinth. Research ensures that the biological control species will not reproduce or feed on plants other than the target species to prevent harm to desirable ones. In addition to direct control, researchers have investigated the use of plant pathogens as mycoherbicides. These pathogens are used with other management techniques and are effective in controlling nuisance aquatic weeds in an environmentally sensitive manner.

Barley Straw

One type of biological control is use of barley straw. First employed in England a decade ago, its use has become widespread. Bales of the substance are introduced into the pond in spring, usually at the rate of four to seven bales per surface acre. The bales may be tethered at the surface with floats or allowed to float freely throughout the pond. In some applications, bales are broken apart and spread about the pond in areas where the weeds are located. Some people place the material in mesh bags and position them near the weeds requiring control. Barley straw should be replaced at intervals throughout the summer and removed entirely in the fall. The method seems particularly effective against filamentous algae but less so against vascular plants. The exact control mechanism of this method is not yet entirely clear and debate in scientific circles still occurs over its efficacy.

Review Questions

1. Which of the following is NOT an example of mechanical control?

a. Pulling, cutting, or raking

b. Using an herbicide in a hand-powered sprayer

c. Dewatering a pond

d. Shading the water to prevent sunlight penetration

2. Physically removing plants from a pond:

a. Is a hard job

b. Provides an effective way to remove nutrients

c. May cause plants to become established elsewhere by fragmentation

d. All of the above

3. Which of the following is NOT an example of biological control?

a. Use of plants to outcompete nuisance vegetation

b. Introduction of herbivorous fish to eat vegetation

c. Use of copper sulfate in hand sprayer

d. Introduction of insects detrimental to target plants

4. Barley straw placed in a pond:

a. Can help to control algae

b. Is not very effective on vascular plants

c. Seems to work by a currently unknown mechanism

d. All of the above

7

Aquatic Herbicides

Herbicides are chemicals that kill plants by disrupting their essential functions. These chemcials can be used to control nuisance vegetation in aquatic environments. When used as intended, they are efficient, cost-effective and, most importantly, safe. A formulation consists of: an organic or inorganic ingredient; an inert carrier; and an adjuvant (may be added to increase effectiveness).

Herbicide Label

Herbicides are required by law to have an attached label that provides information on the chemical, its use, and safety procedures for the applicator and the environment. This label must remain with the herbicide until it is used. It is wise to keep the label as a part of the records required for the application. Herbicides may not be transferred to an improperly labeled container.

Herbicides *may not be used in a manner that is not specified on the label.* It is unlawful to use chemicals in an application that is not specified. An example would be the use of Roundup" on aquatic plants. Instead, Rodeo" is the properly labeled aquatic formulation of glyphosate and may only be used on plants in an aquatic environment. Use of Roundup" for this purpose is a violation of the law. Misusing herbicides not only violates state and federal laws but application can make the water unfit for irrigation, swimming, fishing, or livestock watering.

The label should be read by the applicator and then re-read it to ensure that the herbicide is correct for the intended application. Even if the applicator has read the label in previous applications, it is important to read it again since manufacturers may change the formulation. The Material Safety Data Sheets (MSDS) that accompany the product should also be read and kept with the herbicide and application records.

The following label items should be checked before use:

- *Conditions:* the herbicide must be used in specified conditions of temperature, water quality, weather, and water flow
- *Labeling:* the product must be labeled for the intended use; for example, application to ponds, lakes, rivers, streams, canals, or ditch banks
- *Restricted uses:* such uses must be specified if applicable
- *Restrictions:* length of time to avoid use of treated water for livestock watering, fishing, swimming, irrigation, orchard watering, or consumption as potable water and irrigation
- *Safety equipment:* special equipment that needs to be worn during application
- *Health and safety:* steps to take in case of contact, ingestion, or dermal exposure
- *Signal:* the words DANGER, WARNING, or CAUTION must be specified on the label
- *Target Plant:* product should be identified as able to control the intended plant(s) safely under application conditions

- *Amount:* application rates for the intended use must be specified
- *Timing:* application specified for time of year, stage of plant growth, and related factors
- *Toxicity:* level of toxicity of the product to fish and non-target vegetation

Toxicity categories, signal words, and precautionary statements are included on the product to inform the user about the relative hazard presented by the herbicide (Table 7-1). Each is given a toxicity class (I, II, III, IV) and signal word (DANGER, WARNING, CAUTION). This information is based on the acute (short-term) toxicity of the product in its concentrated state. The label describes precautions necessary when handling the concentrated product. Table 7-1 lists these toxicity categories.

Types of Formulations

Herbicides are rarely used at one hundred percent of formulation and are usually mixed with oil or water in a blend that may include an adjuvant. Adjuvants help the formulation improve its ability to spread, stick, wet, or otherwise assist the solution. These additives improve the measuring, handling, and application of the active compound as it is delivered to the target organism. Herbicides come in several types of formulations. Often the label or trade name of the compound will include the type:

Aqueous Suspension (AS)

This formulation is of low solubility, attached to a carrier, and suspended in water. It is kept suspended through agitation in the tank and agitation of the container before use; most AS formulations settle in storage. Adjuvants may be required to keep the compound and its carrier in suspension for proper application.

Dry Flowable (DF)

This type of fomulation is insoluble but manufactured to be measured and poured. It is more expensive than wettable powders (WP), but easier to handle. The holding tank must be continuously agitated to keep it in suspension during application.

Emulsifiable Concentrate (EC)

These formulations contain petroleum solvents and emulsifiers that can be mixed with water. They do not require much agitation and can have oil- or water-based carriers added when used in low-volume applications. They do not contain abrasives and are easy on application equipment.

Flowable (F)

Flowable formulations contain solids that are insoluble in water and must be suspended in a liquid kept in constant agitation in the tank. They share advantages with emulsifiable concentrates (EC) by being easy on equipment. They do not contain abrasives as a carrier.

Granule (G) and Pellet (P)

These formulations are common. Some compounds are sold in this form or as a liquid for use in certain applications. Both pellets and granules contain an active ingredient placed on clay particles. They are excellent for spot-treating target areas and are easily applied with little chance of drift and can be used directly from the container. They may be

Table 7-1. Herbicide toxicity classes.

Toxicity Category	Signal Work	Oral Toxicity	Skin and Eye Irritation
I Highly toxic	DANGER	Poisonous if swallowed	Corrosive
II Moderately toxic	WARNING	May be fatal if swallowed	Causes eye or skin irritation
III Slightly toxic	CAUTION	Harmful if swallowed	Avoid contact with skin, eyes, or clothing
IV Relatively non-toxic	CAUTION	No statement required	No statement required

Granule and pellet forms of herbicides are useful for spot-treating target areas.

higher in cost for treatment areas, but their effectiveness may offset the price.

Water Soluble Liquids (WSL or L)

Water-soluble liquids are solutions and require no agitation. The herbicides are usually dissolved in a water-soluble solvent, such as alcohol, since they are not used with oil-based carriers. These compounds are most useful when tank agitation is not available.

Wettable Powder (WP, W)

These formulations come as dust and must be constantly agitated after mixing with water to keep the particles in suspension during application. They normally have a high rate of active ingredient, frequently 50 percent or more. Particles can cause wear on spray equipment, but this problem may be offset by the benefits of lower cost and simplicity in measuring and handling.

The Environmental Protection Agency (EPA) registers all herbicides in the United States. Over 200 are registered for use, but only a few are labeled for aquatic application. Some chemcials are effective on aquatic plants, but if the company producing or marketing the herbicides has not obtained aquatic certification, these compounds are not legal to use.

Companies must meet stringent requirements by testing the efficacy of the herbicide while ensuring that it is low in toxicity to humans or other organisms. Registration requirements are costly and must be recouped through sales. If a market does not exist for ensuring adequate profit, therefore, it will not be registered. Some herbicides have been removed from the market because the companies producing and marketing them found that they were not profitable when sold in the aquatic market.

Only 11 chemicals are currently labeled for aquatic use in the United States. Only six are legal in most states: 2,4-D, copper, diquat, endothall, fluridone, glyphosate, and triclopyr. A few others are labeled for use on ditch banks, but are not allowed for water applications.

Properties of Herbicides

Herbicide classification identifies the methods or properties of the compound that controls vegetation (Table 7-2).

- Absorption
  - Contact
  - Systemic
  - Soil active
  - Foliar active
- Physiological processes
  - Nitrogen metabolism and enzyme activity
  - Photosynthesis
  - Respiration
  - Tissue development
- Selectivity
  - Broad spectrum (or nonselective)
  - Selective

Absorption characteristics determine how the herbicide moves. Contact herbicides move very little within the plant and must be in contact with the vegetation to be effective. These herbicides are usually quick acting and effectively kill the cells with which they come into contact. This effectiveness makes them useful for annual, herbaceous plants but less useful for perennials. Submersed aquatic plants need to remain in contact with the herbicide long enough to be controlled although some parts, such as roots, may not be killed. Contact herbicides quickly kill plant surfaces they are applied to; significant die-off is often seen within 24 hours. They fre-

Table 7-2. Herbicide properties.

	Absorption		Processes				Selectivity	
Chemical	Contact	Systemic	Tissue develop-ment	Photo-synthesis	Respir-ation	Nitrogen/ Enzyme Activity	Broad-Spectrum	Selective
Copper	•			•			•	
Diquat	•			•			•	
Endothall	•				•		•	
Glyphosate		•				•	•	
Fluridone		•		•		•		•
2,4-D		•	•			•		•
Triclopyr		•	•					•

quently need re-treatment to remain effective for long periods, requiring two or more applications per year.
Examples of contact herbicides: copper, diquat, endothall

Systemic herbicides move into the plant and are absorbed into living tissue. Although slower acting than contact herbicides, systemics are often more effective for long-term control, especially on woody or perennial plants. Systemic herbicides tend to be more selective than contact herbicides and affect plant parts differently, according to absorption characteristics. For example, roots absorb soil-active herbicides while foliage absorbs foliar-active types of herbicides.
Examples of systemic herbicides: 2,4-D, fluridone, glyphosate, triclopyr

Physiological processes must be assessed when choosing herbicides because chemicals work in different ways. For instance, some affect the cell division in the plant. If an herbicide can stop cell division (hence, growth) from occurring, the plant will slow down or die. Pre-emergence herbicides accomplish this well and affect plants before they populate an area. With unicellular plants, such as some algae, cell division disruption will kill off the population.

Compounds that affect nitrogen metabolism and enzyme activity interfere with basic plant processes. Nitrogen is essential for nutrition and metabolic processes. Enzymes are also essential, helping to move nitrogen through complex biochemical processes that can be targeted by herbicides. Once the enzymes have been affected through interference, the plant has difficulty surviving.
Examples of herbicides targeting nitrogen and enzymes: 2,4-D, fluridone, glyphosate

Photosynthesis is the basic building block of life for plants. Plants use water, sunlight, and carbon dioxide to produce molecules used, in turn, for constructing body and structure. As photosynthesis is a complex process, herbicides that disrupt the activity often cause plant death quickly. To be effective, herbicides that target photosynthesis must be applied on a sunny day when photosynthetic activity is greatest.
Examples of herbicides targeting photosynthesis: copper; diquat, fluridone

Respiration can be affected in plants with herbicides disrupting the process. Since plants produce sugar and carbohydrate compounds during the photosynthesic process and use these compounds through respiration, disruption of respiration can bring about system failure of the target plants.
Example of herbicide targeting respiration: endothall

Tissue development can be used for control. As plants grow, cells develop into specialized tissues

that carry out specific jobs. Some herbicides affect this development by creating abnormalities in the plant that cause it to die. Herbicides that cause this are known as plant growth regulators, or PGRs.
Examples of herbicides targeting tissue development: 2,4-D, triclopyr

Selectivity determines how widely or narrowly the herbicide controls plant species. Broad-spectrum herbicides are used where total control is desired. Such herbicides are frequently used along fence lines where no vegetative growth is wanted. In the aquatic environment, broad-spectrum herbicides are applied in places where clean pond banks are desired.
Examples of broad spectrum herbicides: copper, diquat, endothall, glyphosate

When the intended target requiring control contains only certain plants, selective herbicides are used. Often the choice of an herbicide includes physical factors, such as formulation and rate of application, as well as plant physiological factors, such as the stage of growth at treatment. Selective control of aquatic vegetation is calculated based on how susceptible the plant is to the compound at a particular stage. Selective control is useful when managing water bodies used for recreational fishing or commercial aquaculture.
Examples of selective herbicides: 2,4-D, fluridone

Biological Considerations

Knowing the properties of the plant as well as those of the control agent is necessary when developing a control plan. The applicator must be aware of various factors including morphology of the plant, growth stage, and selectivity of the herbicide at different stages of the plant's development. This information allows the applicator to make the proper choice about the type and amount of chemical to be used, adjuvants for inclusion in the mix, and the method and timing of application. For instance, plants with waxy coatings or hair can prevent herbicide from entering. Also, horizontal broad leaves retain more herbicide than narrow or upright leaves.

Adjuvants may be added either by the manufacturer or the applicator to increase the ability of the chemical to be retained on and to enter the plant. These substances can affect the the herbicide's ability to stick to the plant and facilitate its passage through heavy waxy coatings or thick cuticles. They are useful in selective plant control where only certain stands are targeted for chemical removal. Selectivity can be controlled by the amount of herbicide applied since some plants require application at higher rates to bring about the intended effect.

A plant's growth stage is a factor in the choice of application as well. Some plants are most susceptible to herbicides when young and actively growing; others are more susceptible when mature and in bloom. Soil-active herbicides tend to be most effective with young plants due to their ability to translocate and move throughout the plant, taking them to the most effective sites. Young plants—especially annuals—shift food reserves upward to their growing portions rapidly and will move the herbicide with them. However, other plants, such as perennials, move materials downward when they are finished flowering, which will transport foliar herbicide from leaf surfaces to the roots for better control.

The applicator should always follow the product label for application rates, life stage of treatment, and adjuvants. Based on testing, herbicides are registered for a particular use. Label guidelines should never be ignored or modified.

Adjuvants

Adjuvants help herbicides work better by modifying their action. Historically, they included substances such as soap and fish oils, but modern adjuvants are manufactured for specific purposes and to enhance wetting, foaming, flow, dispersal, and storage.

Advances in their development have led to the availability of several thousand adjuvants. Many are incorporated in the herbicide at the time of manufacture as companies develop new products targeting specific weeds. They assist herbicides in carrying out tasks more efficiently, such as clinging to foliar structures or spreading across them for better coverage. While many people refer to adjuvants as surfactants, this is only true for some. All surfactants are adjuvants, but not all adjuvants are surfactants.

Types of Adjuvants

Adjuvants fall into three main categories. These are: activators, spray modifiers, and utility modifiers.

Activator Adjuvants

These adjuvants increase activity of the herbicide and are related to the particle size of the spray, viscosity, spray distribution to the plant, uptake rate of the plant, solubility of the herbicide in the spray, and the rate of evaporation.

Surfactants

Surfactants are the most commonly used additives and assist in penetration of the foliar tissue by reducing surface tension of liquids. This action aids wetting of the foliar surface and sometimes dissolves leaf tissue.

Wetting Agents

A "wetting agent" is a spray additive that increases the ability of water to displace air or liquids from plant surfaces, helping to spread the spray solution across the plant surface evenly. Surfactants also help with this spreading, but true wetting agents perform the task more efficiently.

Oils

Oil-water emulsions enhance the uptake of herbicide through foliar surfaces by increasing the time of retention on the leaves. Herbicides that come as emulsions usually contain about four parts of oil to one part surfactant. They become milky in appearance when added to water.

Spray-Modifier Adjuvants

These materials modify or alter the spray. They include foams, inverts, and polymers and greatly influence the spray in terms of placement and delivery.

Stickers, Spreaders, Spreader-stickers

These materials are used in many aquatic formulations and aid in spreading and causing spray droplets to adhere to foliage. They include blends of non-ionic surfactants with uncharged particles and are made of vegetable oils or gels, mineral oils, waxes, resins, or latex polymers. Spreader-stickers add two materials and are useful during wet weather but are not normally marketed for aquatic use.

Polymers

Polymers control both drift and sink formulations, which makes them useful for treating aquatic weeds. When marketed as sinking agents, they have a heavy molecular weight and are usually used as emulsions. Their heaviness requires continuous agitation to ensure good mixing, even though they are only mixed in at 0.1% to 1.0% in a formulation. Products for controlling drift require less agitation and are easier to mix.

Inverting Oils

These adjuvants form water droplets surrounded by oil and result in an invert emulsion, generally with a ratio of one part oil to 10–30 parts water. Invert emulsions reduce drift and increase contact time on leaves. They may be used to help sink the formulation. While useful, they require experience and proper equipment for successful application.

Utility-Modifier Adjuvants

The main function of these adjuvants is to improve conditions for the formulation. They include anti-foam agents, co-solvents, buffering agents, dispersants, compatibility agents, coupling agents, emulsifiers, and stabilizing agents. Of these characteristics, buffering and anti-foam agents are most useful in controlling aquatic weeds.

Antifoam Agents

These adjuvants are used at a low level, frequently 0.1% or less of the volume, to reduce or eliminate foam in a spray tank. They are usually made of a silicone base. Foaming is often a greater problem in soft water and some herbicides may come with this type of agent included in the formulation. The product label should be read prior to application for information on the use of adjuvants.

Buffering Agents

These agents increase the solubility of herbicides in acid or alkaline water to aid in dispersion. To increase their effectivity, they are added to the tank prior to the herbicide so they can act on the water before the chemical is introduced.

Foaming Agents

These adjuvants are used with special nozzles to create foam through the induction of air in a venturi. Spray mixtures of 0.1% to 4.0% are normal with these adjuvants.

Choosing herbicides and adjuvants wisely will provide the best control at the least cost while minimizing the labor and other resources that must be allocated to the control project.

Special Considerations: Fish Toxicants

A special case for use of a toxic compound in aquatic environments is in controlling unwanted fish populations. Rotenone has long been used for this purpose. Rotenone is extracted from the roots of tropical plants and is available in both powder and liquid formulations. The substance enters fish through the gills and inhibits cellular respiration, causing death.

Rotenone dosage depends upon the species and size of the fish being controlled, with large fish such as carp requiring higher doses than smaller ones. Fish eggs are more resistant to rotenone than fish. Use of this product in Maryland by other than fish and wildlife agencies is rare; a permit is required for its use from the Maryland Department of the Environment.

The product is usually applied at rates from 0.05 parts per million (ppm) to 2.0 ppm for large fish. Rotenone is applied when water temperatures are above 60° F since detoxification takes longer in colder water. For example, it takes approximately four days for breakdown of the substance to occur at 80° F, but can take up to 14 days for water temperatures at 60° F. To aid in detoxification, potassium permanganate can be used. After use, and before introduction of new fish populations, a small sample of caged fish should be placed in the treated water to evaluate toxicity for 24 to 48 hours before restocking occurs.

Contact your university extension service or state fisheries specialist for information on the use of fish toxicants, calculations on amounts necessary, and the use of detoxifying agents.

Review Questions

1. A formulation can consist of:

a. An inert carrier

b. An adjuvant

c. An inorganic ingredient

d. All of the above

2. Which of the following should be checked on the label before use?

a. Restricted uses

b. Signal word

c. Conditions for use

d. All of the above

3. Place the signal word in order of most toxic to least toxic:

a. Warning, caution, danger

b. Caution, danger, warning

c. Danger, warning, caution

d. Caution, warning, danger

4. Which federal agency registers herbicides for use in the United States?

a. Federal Chemical Agency

b. Environmental Protection Agency

c. Department of Fish and Wildlife

d. Department of Health and Human Services

5. Absorbtion characteristics of herbicides include:

a. Contact and systemic

b. Greater and lesser

c. Broad spectrum or selective

d. Inert and solar

6. Selectivity characteristics of herbicides include:

a. Movement and transport

b. Broad spectrum and selective

c. Photosynthesis and respiration

d. More active and less active

7. An example of a broad-spectrum contact herbicide that targets photosynthesis in control is:

a. Glyphosate

b. Diquat

c. Phosphorus

d. Endothall

8. What does an adjuvant do in a formulation?

a. Adds bulk to the application

b. Helps the herbicide work better by modifying its action

c. Keeps the spray equipment clean

d. Keeps the applicator from having to wear protective clothing

9. Which of the following is NOT an adjuvant?

a. Sticker, spreader, spreader-sticker

b. Antifoam agent

c. Cone nozzle

d. Surfactant

8

Equipment

For successful application to occur, equipment must be matched to the herbicide and the physical factors of the job. Application equipment can be as simple as a hand sprayer or spreader or as complex as boat-mounted power equipment. In some instances, aerial application is effective, especially when treating large areas of surface weeds. When boat equipment is required, several application techniques may be used, according to the vegetation to be treated or type of herbicide formulation.

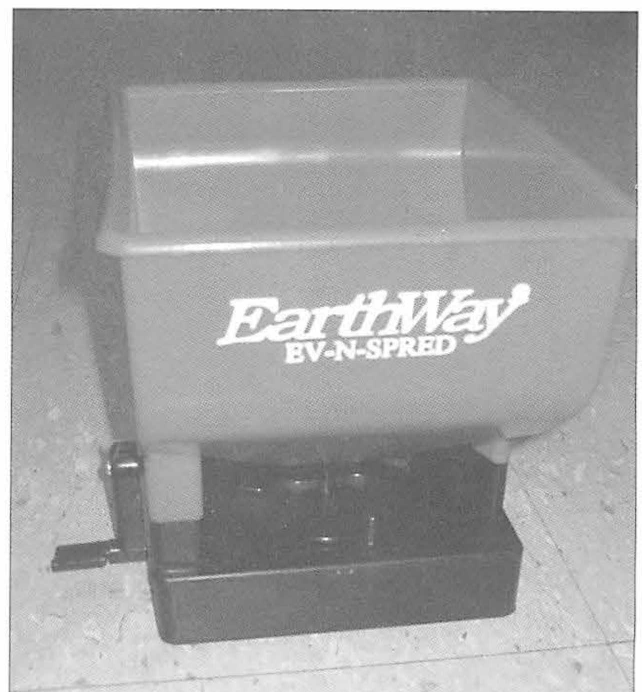
Application Methods

Hand application is the simplest method of treatment. Some granular and pellet herbicides can be spread by hand in areas where vegetation requires control. Some formulations, particularly those applied topically, may come in containers that can be used for application. The herbicide must be properly distributed. Hand application can be imprecise and should only be used where no danger of misapplication exists.

Spreaders are used to apply granular and pellet herbicides. The simplest method is a hand broadcast spreader, often used when applying copper sulfate to shorelines for control of filamentous algae.

Broadcast spreaders contain a bin that holds the herbicide and a rotating disk that spins, throwing material across a wide swath. The operator must walk at a steady pace and turn the unit uniformly to ensure even application. Broadcast spreaders may be fitted to boats when larger areas require treatment, when waters are too deep for easy walking, or when the bottom is too soft and muddy for easy maneuvering.

Blower-type spreaders can be used on boats and have high-volume, low-pressure airflow to shoot granular and pellet formulations over a wide area. Venturis are frequently fitted to the units to move the herbicide into the airstream more effectively. A gas engine up to five horsepower drives the unit, which has the ability to throw herbicides 40 feet or more.



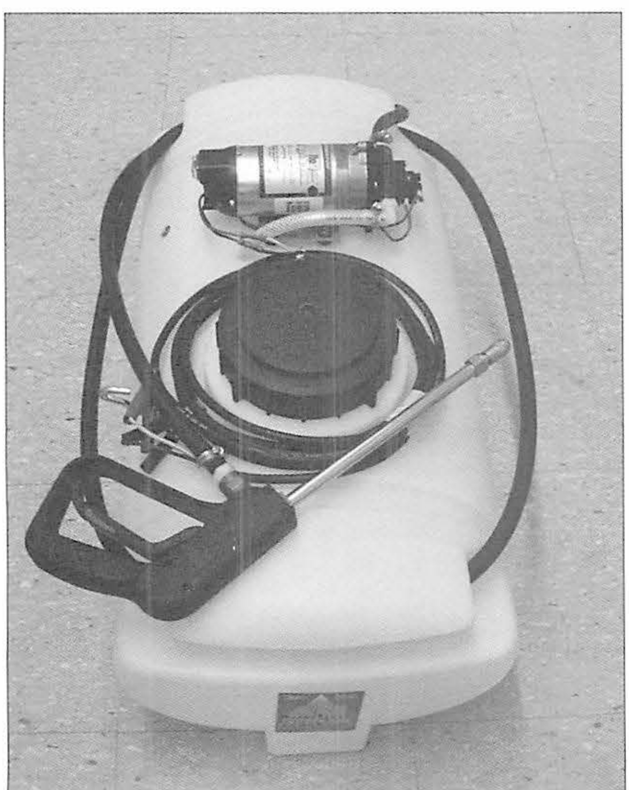
A broadcast spreader, one of several methods for applying pellet or granular herbicides, can be used on land or fitted onto a boat.

Drop spreaders are primarily used on land, although they may by used to treat marginal vegetation along shorelines. The units have a bin that holds herbicide while a paddle moves the bin along a slot that is regulated to allow exact amounts to drop. These units are precise in their delivery, but not generally able to be fitted to boats for waterborne operations.

Sprayers are frequently used to apply herbicides and come in many sizes and configurations. Hand sprayers are typical garden units with a small tank, hand pump, hose, and nozzle. They are useful for spot-treating weeds where entire stands are not targeted for eradication and for mixing small amounts of formulation. They are not useful for formulations that need constant agitation or in large target areas since mixing multiple batches of herbicide takes a great deal of time.

Backpack sprayers are larger units carried by the applicator and are generally more comfortable for moving about. These sprayers consist of a tank, hand pump, hose, and nozzle and are used for treating small areas and targeting application where total eradication may not be desired. They are poor at keeping formulations in suspension.

Power sprayers, which use pumps to deliver liquid herbicides, come in many sizes, from small units powered by a 12-volt battery to larger units that can be fitted onto boats or aircraft.


Hand sprayers are less cumbersome for applying liquid herbicide to small or targeted areas.

Power sprayers are pump systems in many sizes and variations that deliver liquid formulation to target weeds. Small units fit on the back of an ATV or on a garden tractor, using 12-volt battery power for operation. Larger units can be mounted on a tractor or a boat. For aerial application, these sprayers are fitted to an aircraft and can precisely meter proper amounts of herbicide to treat large areas quickly. Power units combine a spray tank to hold the formulation, a pump to move it to the application point, hoses for herbicide delivery, and nozzles to direct the spray. Most units include some type of agitation to keep the formulation in suspension and there may be a metering device to adjust flow to the application point.

Injection units pump metered amounts of liquid herbicide underwater to deal with plants below the surface and are usually designed to treat a wide swath. Application may include a series of light hoses that trail under the surface of the water or

Pump System for Liquid Herbicide Delivery

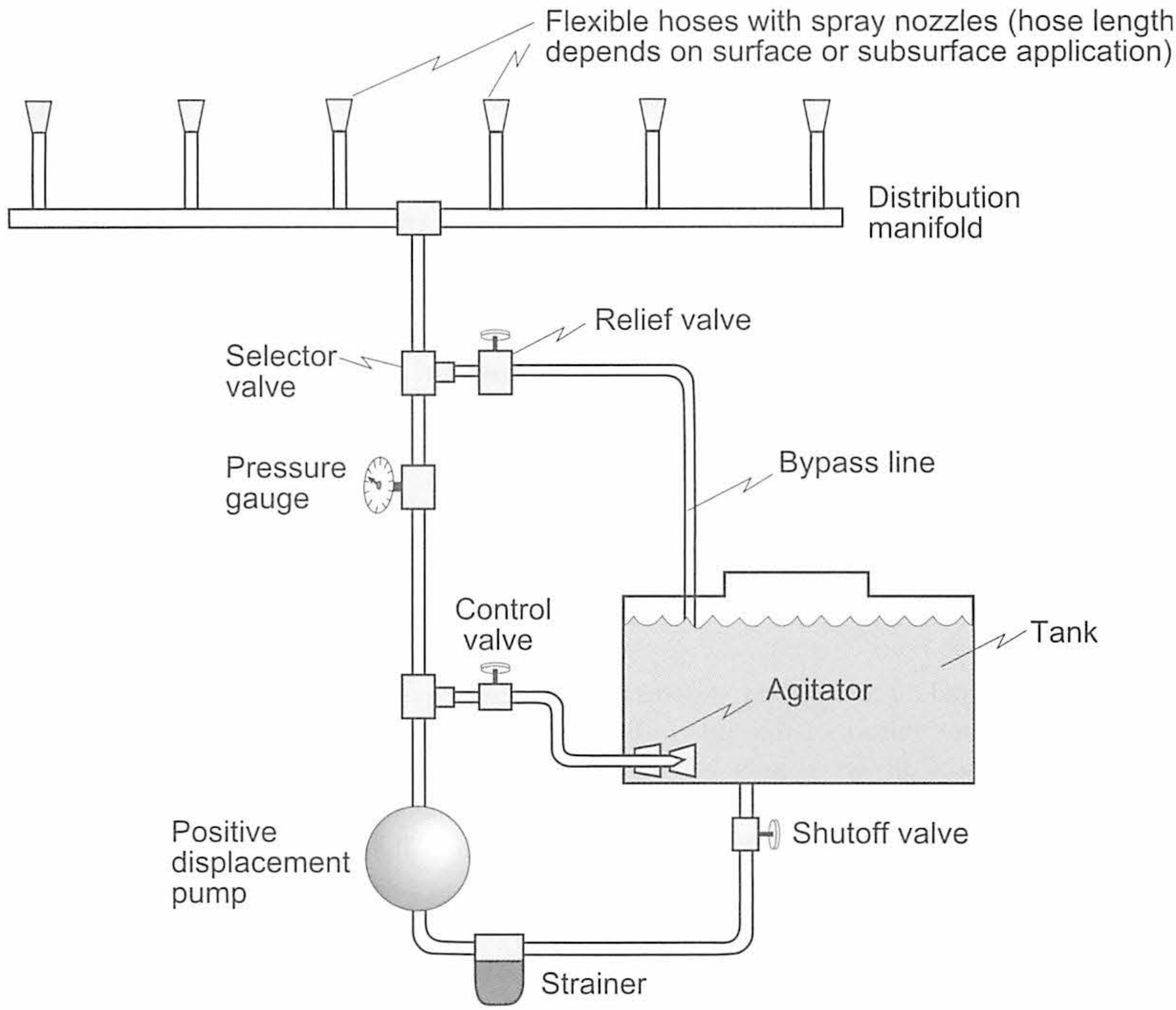


Figure 8-1. Pump systems for delivering liquid herbicides can be built to fit the vessel used for application. An efficient and safe system should include the components shown above.

weighted hoses that hang from the application boat, often running along the bottom, while they deliver metered amounts of herbicide to the plant roots.

Pump Systems

Most powered application systems consist of several components. These systems may come packaged in commercial application units, but can be constructed if necessary to outfit a vessel. In an efficient system each component has a specific function to deliver measured amounts of herbicide to the target weeds.

Spray tanks hold the herbicide formulation—usually the chemical, adjuvants, and a diluant (generally water). Tanks are usually made of plastic or fiberglass to resist the chemicals they hold. The tanks should have large openings for filling and cleaning as well as graduated markings on the side indicating volume levels.

Tanks come in many sizes, shapes, and configurations and the applicator should pick a unit that most closely fits the space where it will be located. In a boat, the tank should be kept from shifting and the weight capacity of the vessel should not be exceeded when the unit is full. A gallon of water weighs over 8 pounds; a 100-gallon tank filled to capacity with water alone would weigh well over 800 pounds. Many herbicides are much heavier than water, making the total weight heavier and potentially creating a dangerous load if calculations are not made beforehand. Spray tanks are most useful when more than one herbicide is used in a mix or for treating limited areas, since refilling is required each time the tank empties during application.

Direct Metering of herbicides is sometimes carried out when large areas require treatment and constantly filling a spray tank would slow application. The herbicide is drawn at a precisely measured rate into the suction side of the pump, while the required diluent is drawn from the water body through intakes built into the boat. Containers of herbicide on board have suction lines tapped into them; a new container is placed online when the previous container is emptied. This system makes these units efficient for treating large water bodies without stopping and reloading the tank several times during application.

Agitation is required for many spray systems to keep the spray mixture uniform. Adjuvants in the formulation will almost always require agitation, especially with polymers or inverting oils. Certain herbicides, such as wettable powders, must be constantly agitated for the material to stay in suspension for proper dispensing to target weeds.

Either hydraulic action or mechanical means can agitate a mixture. Hydraulic agitation occurs by side-streaming the formulation from the pressure side of the pump or by using a venturi to keep materials in suspension. Regulating valves meter the flow rates to the agitator; the nozzle usually controls hydraulic agitation with a high-pressure tap. With this method, the more flow required for proper agitation, the smaller the amount available for delivery of the herbicide through the nozzle.

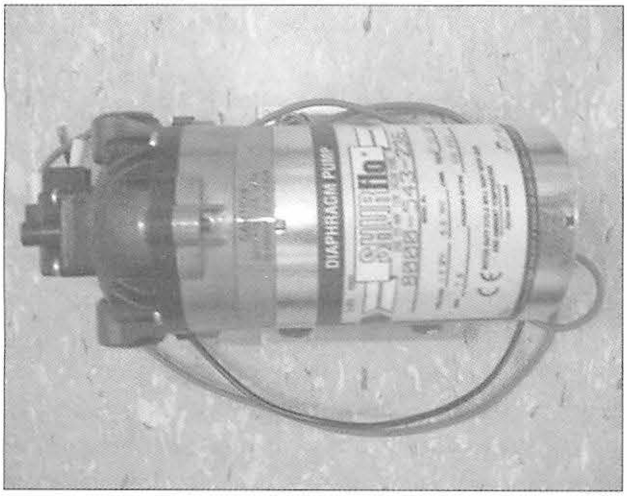
Mechanical agitators are usually paddle-wheel types, which are very efficient at keeping formulations in suspension. They are good when used with invert emulsions or polymers and may be equipped with a clutch so the applicator can adjust the stirring action to keep the formulation at the desired consistency.

Pumps are used to move herbicide from the tank through the system to the point of application. Many types of pumps are available; each has benefits and drawbacks affecting their operation. Generally, pumps are classified by whether they are positive displacement or non-positive displacement. Positive displacement pumps deliver in proportion to their speed since they move a given amount of liquid with each operation cycle. For this reason, positive displacement pumps must include a relief valve and bypass line between the pump discharge and the nozzle valve. Non-positive displacement pumps use a rotating impeller that creates a centrifugal force to move the liquid through the system (rather than moving a fixed volume per cycle). If the nozzle is closed in a centrifugal pump, the impeller will continue to rotate without creating high pressure, so these pumps do not require relief valves.

Centrifugal pumps are non-positive displacement pumps. Because they have few surfaces to wear and need no relief valves, they are easy to maintain and have a long service life. They perform well in pumping corrosive and abrasive materials. During operation, solution enters the center of a housing and into a rotating impeller that can be driven at thousands of revolutions per minute. Solution is forced outward to the housing outlet by centrifugal force for delivery to the application point. Although these pumps can deliver high flow rates against low pressure, they are not usually used in aquatic weed control as they cannot generate high pressure.

Diaphragm pumps are positive displacement units that provide excellent handling with corrosive or abrasive materials since a synthetic diaphragm separates the pumping cylinders from the piston chambers. The units are self-priming, relatively low cost, compact, low maintenance, and can produce medium to high pressures with flow rates of 3.5 to more than 62 gallons per minute. They are popular in spray applications where units can be driven by various means, including gas or diesel engines, or electric motors. Since they are positive displacement, output varies with the pump speed; therefore, the output is constant regardless of the pressure. The unit requires a relief circuit for safe operation.

Roller pumps have a low initial cost and are versatile. These pumps are self-priming and adapt easily to many drive types. When operating, rollers revolve inside the housing and force herbicide



A diaphragm pump is an economical way to spray corrosive or abrasive herbicides, especially where units are driven by gas or diesel engines.

through the outlet to the application point. Roller pumps are popular for on-farm use where they have proved useful in many crop applications. Roller pumps are positive displacement and are usually provided with unloader valves. When the nozzle is shut off, pump pressures rise until the unloader valve unseats, allowing the formulation to bypass the application hose and return to the tank.

Piston pumps are positive displacement pumps that operate like an engine. They have a shaft, pistons, and valves that take in and discharge liquid and deliver relatively low flows, but can reach very high pressure and may operate up to 400 psi. Piston pumps can be driven by either electric motors or gas or diesel engines, depending upon their size. High pressure makes them quite useful in reaching distant areas. They are expensive, however, and output is not steady due to the motion of the pumping pulses from the cylinder. To combat this, these pumps are often fitted with surge chambers or dampeners to even out the flow. Pistons in the pumps are made of various materials; material type should be chosen based upon the formulations they will be exposed to. For most chemical applications, Buna-N rubber or another synthetic material that will not be easily damaged should be used.

Gear pumps are positive displacement units capable of reaching high pressure. When operating, liquid flows through the inlet side of the pump where it enters spaces between the teeth of intermeshing gears. It is then carried to the outlet side where the gears come together, forcing the liquid into the outlet. A disadvantage of these pumps is that the chemical comes in contact with the internal parts, which can cause wear when pumping corrosive materials. They also require an unloading device to direct the liquid back to the holding tank when the nozzle is closed. Gear pumps have largely been replaced in herbicide application by diaphragm and piston pumps.

Hoses direct the liquid from the spray tank to the pump and from the pump to the nozzle and include two types of applications. Suction lines work under a vacuum. As the pump moves liquid outward to the nozzle, it creates a negative pressure in the intake side. Liquid from the spray tank is then pushed in by atmospheric pressure to fill the void. Suction lines must be large enough to move sufficient volume of liquid to replace that flowing out the discharge. Wire or other rigid material usually reinforces the hoses so that they do not collapse under vacuum. An intake hose smaller than the diameter of the pump intake should never be used.

Discharge lines usually work under pressures that are sometimes very high. Lines should be able to withstand maximum pressure without bursting. In all lines, the hoses must be resistant to the chemicals being applied. Common materials used in hoses are ethylene propylene dione monomer (EPDM) and ethylene vinyl acetate (EVA). Hoses and fittings should be checked prior to every application and replaced if cuts, wear points, or leakages exist.

When using long hoses in application, pressure loss will occur due to friction between the liquid and the hose. The highest pressure in the system will be at the pump discharge end of the hose, with the lowest pressure at the nozzle. With a long run and a small-diameter hose, pressure loss can be significant and affect the application distance. Pressure loss is affected by the inside diameter of the hose, hose length, and the flow rate of the pumped material.

Nozzles form the spray pattern, flow rate, and droplet size for the application. These factors need to be assessed for proper choice of the nozzle arrangement, type, and size. Nozzles are critical since they determine the amount of formulation and its placement. Several types are available; selection depends on the characteristics of the vegetation being controlled:

- Handguns are useful in controlling vegetation on the surface and margins as well as on emergent species. These nozzles provide a high flow rate of herbicide that sufficiently wets the target species while minimizing drift to other plants. With proper pumps, handguns can be used to apply herbicide over large areas in a short time.

- Subsurface injection is used to treat submersed aquatic weeds. For shallow water injection, short hoses are spaced at 2-foot intervals on a boom extending across the bow of the boat and out to the sides. Herbicide is metered to the unit and placed under the water close to the target plants. Deeper plants may be treated with a modification of the unit, with weighted hoses distributing the herbicide on or near the bottom of the water body. Known as deep-water injection, this method is useful when systemic herbicides must be placed near the roots of submersed plants. The method is useful in targeting large mats of aquatic vegetation, although care must be taken not to allow hoses to hang up on the plants being treated.

- Aerial applications are used to treat large areas of surface weeds. Such applications use flat fan or hollow cone nozzles to cover the target area. Although fixed-wing aircraft are normally used, helicopters have also been successful in controlling aquatic weeds on the water surface.

Delivery Vehicles

Many vehicles are used to treat aquatic weeds, depending upon the location of the weeds and the techniques used to control them. Aerial application is successful where acres of surface or marginal weeds must be controlled. Tractors and all terrain vehicles (ATVs) have proved helpful in transporting application equipment to marginal areas of lakes and ponds to treat the surrounding shoreline.

A boat is generally the most useful vehicle for working on the water to treat weeds. Boats should be constructed of a sturdy material—fiberglass or aluminum is best—and may have a built-in chemical tank. They can be powered by an outboard gasoline engine or an electric trolling motor for small impoundments where distance and speed are not great. During application, proper safety procedures must be followed and the operator should always clean the boat well before leaving the treatment area. Failure to clean the boat properly can allow fragments of vegetation to cling to the boat, motor, trailer, and vehicle, possibly leading to infestation of other water bodies when the boat is launched elsewhere. Weed fragments can survive long periods before becoming active again.

Proper maintenance and sanitation should be part of any aquatic application. The vessel, trailer, and vehicle, as well as all equipment, should be thoroughly washed and scrubbed with brushes, preferably before leaving the site and always before entering another waterway. Power washing in an area where fragments of vegetation cannot flush into other waters is good practice. All areas of the trailer and boat—including behind lights, license tag, and motors—should be washed to remove all particles from the spray vehicle. Visual inspection of the rig after sanitizing is necessary to ensure that no particles remain.

Review Questions

1. A broadcast spreader would be used when applying:

a. Liquid diquat and a surfactant to floating vegetation

b. Copper granules to nearshore filamentous algae

c. A liquid contact herbicide to submerged vegetation

d. Barley straw to control water lillies

2. What application equipment would NOT likely be used on a boat?

a. Injection unit

b. Power sprayer

c. Drop spreader

d. Blower-type spreader

3. Agitation is required in many spray systems because:

a. It helps to keep the spray mixture uniform

b. It helps to keep wettable powders in suspension

c. It keeps polymers and inverting oils from settling out

d. All of the above

4. Why aren't centrifugal pumps used often in aquatic weed control?

a. They are too expensive

b. They break down too frequently

c. They are not able to generate the high pressure required

d. They are not an actual pump type

5. Which statement about diaphragm pumps is NOT true?

a. Diaphragm pumps are positive displacement pumps

b. Diaphragm pumps work well with corrosive or abrasive materials

c. Diaphragm pumps are not self-priming and require a priming circuit for use

d. Diaphragm pumps are able to produce medium to high pressures

6. Which of the following is NOT a type of nozzle application?

a. Handgun

b. Aerial

c. Subsurface injection

d. Broadcast spreader

9

Calculating Applications

Herbicide labels contain information about the rate of application for target weeds. Adhering to these guidelines is necessary to avoid mistakes that could kill non-target plants or animals. Since herbicides are costly, using only the prescribed amount saves money. Additionally, all applications need to be made within requirements of applicable laws and regulations. Adhering to label recommendations allows the applicator to meet these goals.

To calculate the amount of herbicide needed for a particular application, it is necessary to know the size of the intended application and the herbicide application rate. The application rate will be provided on the label, listed as: gallons or pounds per acre (either per surface acre or acre/foot); percent solution; or concentration of active ingredient in water (as parts per million or milligrams per liter).

Area Calculations

The first piece of information an applicator needs is the size of the water body being treated. This area is often calculated in square feet (sq ft) or acres (A). Small bodies of water can be measured by tape. Modern range-finding equipment has become increasingly inexpensive and proves useful in measuring long or irregular distances. Since the Natural Resources Conservation Service (NRCS) assisted in the construction of many ponds, visiting the local NRCS county office to determine if engineering drawings of the pond are on file is advised. The NRCS offices also house photogrammetric maps of the county; size can be calculated from these maps using a planimeter.

Simple geometry can be used for many calculations. Many ponds are rectangular or some other basic geometric shape that makes computing surface acreage fairly easy. Combining several geometric shapes to best estimate the pond's area will yield the greatest accuracy, which is important in the application of herbicides.

Basic Geometric Calculations

One acre contains 43,560 square feet. Dividing the measured square footage by this number yields the number of acres.

Rectangular bodies of water are easily calculated by multiplying the length times the width.

$$\textit{Area of rectangle} = \frac{\textit{length (ft)} \times \textit{width (ft)}}{\textit{43,560 (sq ft per acre)}}$$

Example: Calculate the acreage of a pond 650 feet by 500 feet:

$$\textit{Surface acres} = \frac{\textit{650 ft} \times \textit{500 ft}}{\textit{43,560 sq ft}}$$

$$\textit{Surface acres} = \textit{7.46 acres}$$

The triangle is a basic shape easily calculated by multiplying one-half of the base times the height and dividing by the number of square feet in an acre.

$$\textit{Area of triangle (acres)} = \frac{\textit{½ base (ft)} \times \textit{height (ft)}}{\textit{43,560 sq ft per acre}}$$

Example: Calculate the acreage of a triangle with a base of 450 feet and a height of 700 feet:

$$\text{Surface acres} = \frac{(450/2)\ ft \times 700\ ft}{43{,}560\ sq\ ft}$$

Surface acres = 3.62 acres

Circular calculations use the constant B (pi) (3.14 times the square of the radius) to obtain the size.

$$\text{Area of a circle (aces)} = \frac{3.14 \times radius\ (ft)^2}{43{,}560\ sq\ ft\ per\ acre}$$

Example: Calculate the acreage of circle with a radius of 500 feet.

$$\text{Surface acres} = \frac{3.14 \times (500)^2}{43{,}560\ sq\ ft}$$

Surface acres = 18.03 acres

Bodies of water can often be divided into geometric sections to calculate total size (Figure 9-1). The largest area of the water body is rectangular in shape, with a triangular section on one side. We can use different formulas for these sections and add them to calculate total area. Such calculations will often have to be made because bodies of water are rarely perfectly shaped and are usually designed to fit within land contours and to account for other factors. An exception is ponds specifically designed for aquaculture, which tend to have straight sides to facilitate seining of the crop.

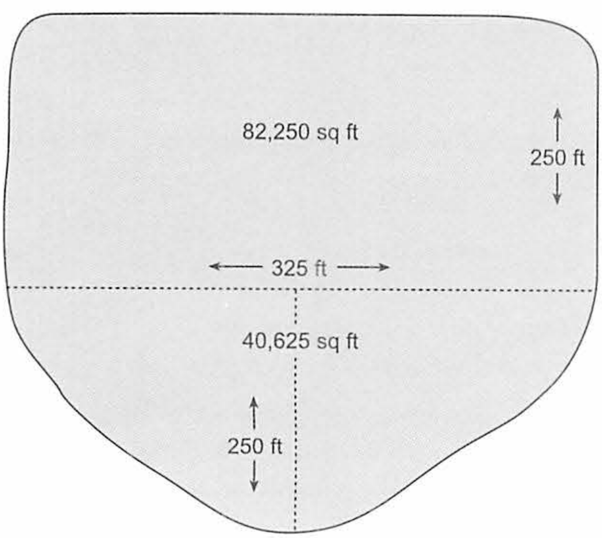


Figure 9-1. Dividing a pond into geometric shapes is the simplest and most accurate way of calculating the total size of a pond.

Example: Calculate the area in surface acres of the pond in Figure 9-1:

$$Area = \frac{(325 \times 250) + (325/2 \times 250)}{43{,}560\ sq\ ft\ per\ acre}$$

$$Area = \frac{81{,}250 + 40{,}625}{43{,}560}$$

Surface acres = 2.8 acres

Often only areas where weeds are actually growing need to be measured for treatment. In this case, creating a layout with treatment areas as blocks of geometric shapes allows an accurate calculation of the total. This method is also recommended when danger of causing oxygen depletion in the water body exists due to decay of the treated vegetation. For instance, during hot summer months, treating only one-third to one-half of a body of water at a time is recommended to allow sufficient time for the weeds to die and decompose before moving on to the next section. In situations such as this, laying out the treatment area in geometric blocks will facilitate calculations for partial treatment.

Determining Volume

Determining the volume of a body of water is sometimes needed for proper calculation of herbicide quantities, such as when an application is based on a percent solution or as a concentration of an active ingredient in the water. Most of these calculations will be based upon an acre-foot of water, defined as 1 acre of water 1 foot deep. A pond that is 4 surface acres in size with an average depth of 2 feet will contain 8 acre-feet of water. A 2-acre pond that averages 1.5 feet in depth will contain 3 acre-feet. An acre-foot of water contains 43,560 cubic feet of water or 325,850 gallons and weighs 2,718,144 pounds.

Whenever volumetric calculations must be made, water depth will need to be measured. Water depth can be measured using a stadia rod or pole marked with standard units progressing from the bottom upward. An echo sounder can also take depth readings at prescribed intervals while a vessel runs along a transect line. If this is used, the depth from the surface to the face of the sounder's tranducer will need to be added to the reading. This equipment allows the applicator to measure depths that exceed a measurement rod and to take more measurements quickly to ensure an adequate number of calculations.

To determine volume, a series of depth measurements are taken at intervals throughout the body of water. These depths are then added and divided by the total number of readings to obtain an average depth. This total can then be multiplied by the surface acreage to obtain the volume.

Example: We measured a pond and calculated its surface area as 2.8 acres (Figure 9-2). We laid out transects and took soundings in two lanes across the pond with a stadia rod marked in feet. On transect #1, the depth readings were: 1, 1, 2, 3, 3, 4, 5, 6, 4, 3, 2, and 1. On transect #2, the readings were: 1, 1, 2, 3, 4, 5, 6, 4, 3, 2, 1, and 1. We calculated the average depth by adding all the measurements and dividing by the total number.

$$\text{Average depth} = \frac{(1+1+2+3+3+4+5+6+4+3+2+1) + (1+1+2+3+4+5+6+4+3+2+1+1)}{24}$$

Average depth = 2.83 feet

Pond volume = Area x depth =
2.8 acres x 2.83 feet = 7.93 acre-feet

Applications by Rate

We can use the previous example to calculate an application of herbicide. In this case, the label recommends that we apply a granular herbicide at the rate of 60 pounds per acre.

Herbicide required =
pounds per acre x number of acres =
60 lbs/acre x 2.8 acres

Herbicide required = 168 pounds

Applications by Concentration

Some herbicides are applied at a certain concentration for a body of water. Concentrations are generally expressed in parts per million (ppm). To calculate the concentration, the volume of water must be known. This number can then be related to gallons or weight, although the calculation is more often based on weight.

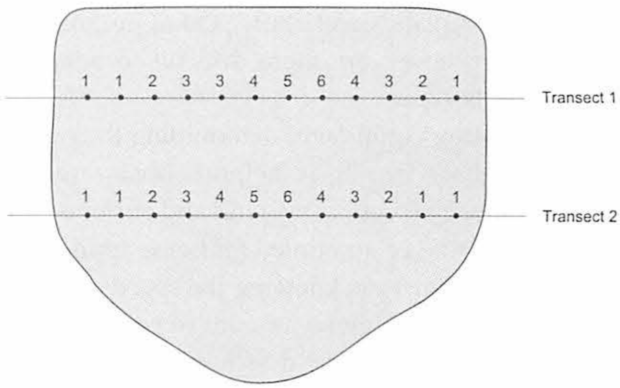


Figure 9-2. Water depth must be measured in order to calculate pond volume, which is necessary for determining the proper quantities of herbicide to apply.

Data from the previous example are used to calculate a treatment of endothall based on a concentration of 1.5 ppm. We knew the area of the pond and measured the depth; we then calculated the average depth, multiplied it by the area, and obtained a total volume of 7.93 acre-feet. To determine the amount of herbicide, we multiplied the concentration required in ppm (in this case, 1.5) by the volume in acre-feet (7.93 times the constant, 2.7). The constant 2.7 is based on the weight of an acre foot of water (2,700,000 lbs); 1 ppm would be 2.7 lbs in 2.7 million lbs of water.

Herbicide required = ppm x acre-feet x 2.7

Herbicide required = 1.5 x 7.93 x 2.7 = 32.12 lbs

Calibrating Application Equipment

For successful application without herbicide waste, the application equipment must be preceisely calibrated. While calibration can be accomplished quite precisely on land, other factors interfere in the aquatic environment. Tractors move in straight lines on land; boats are vastly different and are influenced by winds, currents, and tides. Calibrating application equipment carefully will allow control of aquatic weed problems with a minimum of trouble or wasted material.

Some equipment used on land, such as backpack sprayers or broadcast spreaders, may be easily adapted to aquatic treatments. Other techniques, such as drip hoses, are more difficult to adapt to aquatic applications.

In adjusting equipment, determining the rate at which the boat travels is helpful. Boats are frequently moved off course by wind and currents—an effect that should be accounted for in the application procedure. At any rate, knowing the speed at which the boat moves at a given amount of power is key. With an outboard engine, a tachometer senses the revolutions per minute of the engine. For electric trolling motors, using marked power settings can yield reasonably reliable speed data.

The relationship among time, speed, and distance is useful in aquatic application. Vessel speed can be determined by using a marked distance and running between these two marks at least twice to obtain an average time. By knowing distance and measuring time at a given engine rpm, calculating the speed of the vessel is simple. The information can be stored as a reference sheet for future use. When making calculations, it is important that the boat be as close to operating conditions as possible. For instance, if treatment is usually carried out with two people aboard, then tables should be calculated with two people of approximately the same weight aboard the vessel. Application equipment should also be aboard and be half full of the intended formulation to obtain an accurate average number.

$$mph = \frac{\text{distance traveled (ft)} \times 3{,}600}{5{,}280\ ft \times \text{time in seconds}}$$

Example: We use a marked course of 100 feet and time the boat through two trials. It takes 23 seconds to complete the first run and 27 seconds to complete the second one. The average run, therefore, is 25 seconds.

$$mph = \frac{100\ ft \times 3{,}600}{5{,}280 \times 25} = \frac{360{,}000}{132{,}000}$$

$$mph = 2.73$$

In addition to knowing the boat speed at various power settings, successful applicators will constantly evaluate and calibrate all application equipment, including sprayers, nozzles, and spreaders used in aquatic herbicide application. Knowing the output of this equipment in a given time period allows accurate application. Putting too much herbicide in the water create unintended consequences, such as fish kills or destruction of non-target plants. Placing too little herbicide in contact with the target plants can lead to expensive repeat treatments. Equipment that is poorly maintained and calibrated may cause variation in application with "hot spots" occurring in some areas and deficiencies in others.

For information on calibrating spray or other application equipment, contact your local Maryland Cooperative Extension office. Fact sheets and videos are available that can provide information on this subject. While not strictly for aquatic use, the principles and techniques are applicable to treatment in this environment.

Review Questions

1. ***Application rates are given on the herbicide label as:***
   a. *Percent solution*
   b. *Gallons or pounds per acre*
   c. *Concentration of active ingredient in water*
   d. *Any of the above*

2. ***A rectangular pond 700 feet x 1,000 feet would cover approximately:***
   a. *0.16 acres*
   b. *1.6 acres*
   c. *16 acres*
   d. *160 acres*

3. ***If that same pond had an average depth of 3 feet, how many acre-feet would it contain?***
   a. *0.48 acre-feet*
   b. *4.82 acre-feet*
   c. *48.2 acre-feet*
   d. *482 acre-feet*

4. ***An acre-foot of water weighs 2,700,000 pounds. An herbicide must be applied at a rate of 1 part per million (ppm). How many pounds will need to be applied to 5 acre-feet of water?***
   a. *.135 pounds*
   b. *1.35 pounds*
   c. *13.5 pounds*
   d. *135 pounds*

5. ***We are calibrating the speed of our boat at a given rpm. A course 100 feet long takes us an average of 17 seconds to complete. The average speed of our boat is:***
   a. *0.4 mph*
   b. *4.0 mph*
   c. *40 mph*
   d. *400 mph*

10

Safety

Aquatic applicators operate in an environment that requires special safety considerations. In addition to adhering to safety procedures for handling chemicals, an additional burden of ensuring that boating and aquatic safety procedures are followed also exists. Boating safety studies have shown that people using a boat while engaged in activities such as hunting and fishing often do not consider themselves to be "boating." This lack of awareness has led to many boating deaths over the years.

Aquatic applicators may believe that they do not have to adhere to basic boating safety requirements since they often operate on small, privately owned ponds. Also, they may think that since these ponds are often small and shallow, they will not encounter difficulties during herbicide application, or can simply walk or swim ashore in the event of an accident. This assumption is not only false, but can prove deadly. Safety is everyone's concern and should be foremost in the minds of applicators. Boating safety regulations help the public remain safe while operating on the water. These regulations are logical, easy to adhere to, and do not place unnecessary burdens on applicators who understand and follow them.

Chemical Protection

Aquatic applicators must adhere to all regulations and responsibilities in using personal protective equipment (PPE), including coveralls or protective suits, footwear, gloves, aprons, respirators, eyewear, and headgear. The label on the chemical being used contains instructions for required PPE. This information is covered in detail in the Core Manual.

Water Safety Equipment

In addition to PPE, applicators need to use safety equipment when on or near water. At a minimum, applicators should always wear personal flotation devices (PFDs). These devices come in an assortment of types, ranging from the large Class I types used on ocean-going vessels to the light and easy-to-use Class III versions.

Recent innovations have made this equipment lighter, cooler, and easier to use. Simple work vests may be worn in summer months; in cooler weather, flotation jackets provide warmth and utility. Some vests and jackets are sold with minimal inherent

Working on or near water always poses a danger. A basic piece of safety equipment those applying herbicides should always have and use is a personal flotation device, or PFD.

flotation, but have bladders that inflate quickly with compressed gas cylinders that discharge with the pull of a lanyard. Work suits that contain foam flotation throughout the torso, arms, and legs provide protection from hypothermia in cold water. Applicators should carefully consider the type of PFDs since some are not designed to turn the wearer face up in the event of unconsciousness. Before purchase, applicators should consider the operating environment, proximity of other crew members for potential rescue, and other factors that could affect the safety of the operation.

The PFDs should be worn even with shoreline application since the edges of water bodies frequently have slippery slopes. Working on or near dams or other structures can also be dangerous since these areas are often slick due to aquatic plant growth.

Proper footwear is also an important part of the safety equipment. Rubber boots designed specifically for boating are available with non-slip soles. These boots have slits cut into the soles that provide traction on wet surfaces such as boat decks. Rubber or similar compounds protect the applicator and allow proper sanitation and cleanup after use. Leather boat shoes are not recommended since they provide poor protection; chemicals will soak into them and come in contact with the applicator's skin. Under no circumstance should an applicator go barefoot or use sandals.

Equipment is widely available in boating stores or through catalogs. The key to protection on the water is choosing good safety equipment, training with it, and *using* it. A PFD left on the shore won't help when you fall overboard into a lake or pond.

Vessel Safety

Because of the nature of aquatic application, boats should be carefully rigged to ensure safety for workers as well as protection for the environment. Wide, flat-bottomed boats offer the stability required when moving chemicals. Tanks should be secured so they cannot shift and should be situated so the boat is in proper trim during application. Chemical boats are available with the tanks permanently fixed.

Boats constructed of aluminum or fiberglass are easily cleaned and sanitized; wood boats may allow chemicals to soak into the wood fibers, making them difficult to clean. Always check the capacity plate located in the boat's stern for safe loading information. This plate will note the maximum load that the boat can safely carry and the maximum horsepower of the engine used for power. Most modern boats are required to comply with level flotation standards ensuring that the boat will float at gunwale height even if filled with water. To comply, boats are often fitted with foam flotation under seats and in enclosed compartments. Under no circumstance should this flotation material be removed.

If application requires personnel to stand while working, the boat should be fitted with rails and platforms so that workers cannot be thrown off balance or fall overboard. Padded rails provide additional safety for the crew. A basic standard of boating safety is that one should never stand in a boat without some means of restraint.

Boats used for application are often low in freeboard. Care should be taken to use them only during weather conditions that are safe for these vessels to be out on the water. High winds or waves can wash over the side, causing a vessel to take on water. In addition, thunderstorms arise quickly during the summer and often bring high winds. Boats should never be caught on a body of water during these storms without protection for crews. Maneuvering in wet boats, especially those constructed of metal, requires constant vigilance to ensure safe operation.

Other Considerations

When applying chemicals from a boat, only a properly mixed tank should be on board. When that tank is exhausted, the crew should return the vessel to shore to mix another batch. The bulk chemical container should *never* be stored on board during application. If the boat should capsize or sink, bulk chemicals would pose special hazards that could affect both the crew and the environment.

After the crew members complete the application, they should ensure that the vessel does not carry any aquatic vegetation that could spread to other locations. This precaution is particularly necessary when treating plants such as duckweed or watermeal, since their leaves can readily adhere to the hull and motor of the boat or the boat trailer. A place should be established to wash down the unit after use and to sanitize it so that nuisance vegetation is not spread by the applicator.

Review Questions

1. ***Why should an applicator on a boat always wear a personal flotation device (PFD)?***

   a. *It can help you survive in the event you fall overboard*

   b. *Some types can hold your head out of the water if you become unconscious*

   c. *Application work can take place in slippery areas*

   d. *All of the above*

2. ***Why shouldn't a bulk chemical container be taken on board the application vessel?***

   a. *It doesn't look good to have a big container on a boat*

   b. *If the boat capsizes or sinks it could cause a potentially dangerous spill*

   c. *Bulk containers might scare fish*

   d. *The container doesn't have a bulkhead fitting*

Answers to Review Questions

Chapter 1:

1c - Altitude

2b - Rises during the daylight hours and declines at night

3b - Phosphorus

Chapter 2:

1b - 3 feet of water

2b - The area that drains into the water body

3d - All of the above

Chapter 3:

1b - Warm water contains more dissolved oxygen than cold water

2c - A pH of 3.0 is healthy for fish

3d - All of the above

Chapter 4:

1b - Terrestrial

2c - Algae poses no problem for a pond at any density

3a - Floating plants have no true root or stem system

4c - Potomogetons, or pondweeds, are not part of the submerged classification

5c - Emergent plants never spread through rhizomes

6c - Marginal plants are never a problem if they can be kept on levees or dams

Chapter 5:

1c - Identify the plant(s) needing control

2b - Department of the Environment

3d - All of the above

Chapter 6:

1b - Using an herbicide in a hand-powered sprayer

2d - All of the above

3d - Use of copper sulfate in a hand sprayer

4b - Is not very effective on vascular plants

Chapter 7:

1d - All of the above

2d - All of the above

3c - Danger, Warning, Caution

4b - Environmental Protection Agency

5a - Contact and systemic

6b - Broad-spectrum and selective

7b - Diquat

8b - Assist in modifying the herbicide to work better by modifying their action

9c - Cone nozzle

Chapter 8:

1b - Copper granules to nearshore filamentous algae

2c - Drop spreader

3d - All of the above

4c - They are not able to generate high pressures required

5c - Diaphragm pumps are not self-priming and require a priming circuit for use

6d - Broadcast spreader

Chapter 9:

1d - Any of the above

2c - 16 acres

3c - 48.2 acre-feet

4c - 13.5 pounds

5b - 4.0 mph

Chapter 10:

1. d - All of the above

2. b - If the boat capsizes or sinks it could cause a potentially dangerous spill

Review Questions

1. ***Why should an applicator on a boat always wear a personal flotation device (PFD)?***

   a. *It can help you survive in the event you fall overboard*

   b. *Some types can hold your head out of the water if you become unconscious*

   c. *Application work can take place in slippery areas*

   d. *All of the above*

2. ***Why shouldn't a bulk chemical container be taken on board the application vessel?***

   a. *It doesn't look good to have a big container on a boat*

   b. *If the boat capsizes or sinks it could cause a potentially dangerous spill*

   c. *Bulk containers might scare fish*

   d. *The container doesn't have a bulkhead fitting*

after use and to sanitize it so that nuisance vegetation is not spread by the applicator.

Appendix I
Glossary

Acre-foot – A volumetric measurement equal to one acre of water one foot deep.

Active ingredient – The chemical or chemicals in an herbicide that are responsible for the effectiveness of the product.

Adjuvant – An additive that assists in improving the activity of an herbicide or its application.

Adsorbtion – A chemical process in which an herbicide adheres to a surface.

Aerobic – In the presence of oxygen.

Algae – Simple plants that have no differentiated true roots, leaves, or stems.

Algicide – A chemical that kills algae.

Anaerobic – Without oxygen present.

Anoxic – Without oxygen, a condition lethal to fish and other pond life.

Aquaculture – The propagation of aquatic plants or animals under controlled circumstances.

Band treatment – Application to a continuous linear area such as the periphery of a pond.

Benthic – The organisms that live on or in bottom sediments.

Biochemical oxygen demand (BOD) – A laboratory test to determine the amount of oxygen required to decompose organic materials and oxidize inorganic substances during a given time period.

Broadcast – A treatment that is applied over an entire area such as a pond.

Carcinogenic – A substance with the capability of causing or leading to cancer in animals.

Carrier – A substance used to suspend an herbicide during application.

Chelate – Combination of a metal ion and an inorganic molecule that makes the metal ion less reactive with other chemicals in water or soil.

Common name – (a) The name most often used to refer to a plant which is not its taxonomic or scientific name; (b) The short name commonly used to refer to the active ingredient in a herbicide.

Concentration – The amount of active ingredient in a diluent expressed as a portion of the total (e.g., lbs/gal, kg/l, percent).

Dessicate – To dry up or lose moisture.

Diluent – A substance used to reduce the concentration of the active ingredient in the formulation.

Directed application – Applying herbicide to a precise area or spot on the plant.

Dissolved oxygen – Oxygen dissolved in water, necessary for fish and other aquatic animals to breathe.

Effluent – Water that flows outward from an impoundment.

Emergent – Rooted plants with most of the stem and leaf tissue above the water surface.

Emulsifier– Surface-active substance that promotes suspension of one liquid in another.

Emulsion – Suspension of one liquid in another as small globules.

Eutrophication – A condition caused by the presence of too many nutrients, too much algae, and too little dissolved oxygen. Eutrophic waters are usually murky, with poor light penetration.

Filamentous algae – A plant that grows in long hair-like strands of cells with filaments that can be branched or not.

Floating plant – Plants that are free-floating or anchored and adapted to grow with most vegetative tissue at or above the water surface.

Flowable – Two-part formulations that contain a solid herbicide suspended in a liquid and that forms a suspension when added to water.

Foliar application – The process of applying herbicide to leaves or foliage of plants.

Formulation – A recipe for herbicide prepared and supplied by the manufacturer for use.

Herbicide – A chemical used to control or kill plants by interrupting their growth process or vital functions.

Invert emulsion – Suspension of water droplets in an oil phase.

Label – Attached printed material that accompanies an herbicide product and contains directions relating to application, safety, restrictions, storage, disposal, and other critical information approved for that product through the registration process.

LC50 – The concentration of a chemical that will kill 50 percent of the organisms in a specific test.

LD50 – The amount of a chemical calculated to be lethal to 50 percent of the organisms in a specific test. This may be expressed in oral, dermal, or inhalation terms.

Macrophyte – A plant that is large enough to be seen without the aid of a microscope.

Non-ionic surfactant – An additive used in a spray solution to improve its ability to stick and wet the surface without use of an electrical charge.

Non-selective herbicide – A product that is toxic to plants without regard to species; its toxicity may be a function of timing, dosage, or method of application.

Non-target species – Species not intended to be killed or affected by a herbicide.

Noxious weed – Weeds that have been specified by law as necessary to control because they exhibit troublesome or undesirable characteristics.

Parts per million (ppm) – One part of a substance in one million parts of another.

Pelleted – Herbicide placed with other components in a dry formulation larger than 10 cubic millimeters and usually broadcast or dropped with a liquid carrier onto the intended treatment area.

Photosynthesis – The process by which a plant converts carbon dioxide and water into sugars using sunlight.

Phytoplankton – Small, often microscopic plants that grow as single cells, small colonies, or filaments.

Plankton – Small, often microscopic organisms that drift or float in the water.

Precipitate – Formation of solids that result when a substance will not remain in solution.

Rate – The amount of ingredient applied to a unit area (e.g., lbs per acre, ozs per acre-foot)

Registration – A governmental process by which a pesticide is legally approved for use by the US Environmental Protection Agency under provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

Residue – Herbicide remaining in plant or animal tissue, surfaces, or soil.

Rhizome – Root-like underground stem, usually moving horizontally and capable of producing plant shoots from the top and new roots from the bottom.

Scientific name – A taxonomic means of identifying plants in Latin so that they may be properly categorized and broadly understood.

Selective herbicide – An herbicide more toxic to some plants than others.

Soil application – An application made to the soil instead of the plant.

Solution – A mixture of two or more substances that becomes homogeneous.

Spot treatment – Herbicidal treatment of small areas or patches within a larger area.

Spray drift – Movement of an airborne spray away from the intended target area.

Stratify – The process of separating one level from another, as when a layer of warmer waters overlies cooler, denser waters.

Submerged plant – An aquatic plant with all or most of its vegetative tissues below the surface of the water.

Surfactant – A substance that improves the ability of a formulation to spread, wet, or disperse on the surface of a plant so that the properties of the herbicide can be modified.

Suspension – A mixture that contains fine particles evenly dispersed in a liquid, gas, or solid.

Systemic – Herbicides that translocate within plants, disrupting internal biological processes required for their survival.

Tank mix – Combining two or more chemicals in a spray tank at one time.

Tolerance – (a) The amount of residue tolerated on or in agricultural products; (b) The capacity of a plant to withstand herbicide application without deviating from normal growth or function.

Toxicity – The ability of a substance to cause injury or illness.

Toxicology – Study of the principles and methods of toxicity.

Trade name – The name given to a product by the manufacturer.

Translocated – Movement of herbicide that occurs within the plant from the point of initial application (e.g., an herbicide that is applied to the leaves of a plant and moves downward through the phloem to the roots).

Tubers – Vegetative (asexual) buds (buried in the sediment) usually forming at the end of runners; capable of remaining dormant before developing into new plants.

Turions – Vegetative (asexual) buds usually formed in the leaf axils or stem tips; capable of remaining dormant before developing into new plants.

Vapor – A substance in its gaseous state, normally changing from the liquid state.

Vascular plant – Plant with specialized conductive tissue.

Watershed – That area that drains into a body of water and which contributes to its surface water supply.

Weed – A plant growing where it is not wanted.

Wetting agent – a) A substance that helps spray or suspension solutions make better contact with plant surfaces; b) A substance in wettable powder formulations that cause these formulations to wet more quickly when added to water.

Wettable powder – Fine particles of dry formulation that are suspended in water.

Zooplankton – Microscopic animals found within the water that feed upon phytoplankton and are in turn fed upon by aquatic fish and insects.

Appendix II
Aquatic Weed Analysis Data Sheet

Date: **Time:**

Location: **Investigator:**

I. Description of Water Body

Type: Pond [ ] Lake [ ] Ditch [ ] Reservoir [ ] Stream [ ] River [ ]
Other (specify):

Water Source: Runoff [ ] Flowthrough [ ] Groundwater [ ] Well [ ]
Other (specify):

Control Structure: None [ ] Spillway [ ] Dam w/ boards [ ] Standpipe [ ]
Other (specify):

Water Use(s): Swimming [ ] Irrigation (Crop, Orchard, Turf, Other) [ ] Fishing [ ]
Aquaculture [ ] Livestock (Dairy, Beef, Poultry, Swine, Other) [ ] Firefighting [ ]
Other (specify):

Downstream water uses:

Current water depth: Above average [ ] Average [ ] Below average [ ]

Dimensions: (attach diagram w/measurements; note weed coverage areas)
Area (acres) Average depth (feet)

Observed nutrient sources: Animal waste [ ] Street drainage [ ] Fertilized fields/lawns [ ]
Septic systems [ ] Other (specify):

Measurements:

pH Ammonia

Alkalinity Nitrite

Dissolved oxygen Nitrate

Salinity Tannin/lignin

Other (specify):

II. Identify Aquatic Weed(s)

Type:

Algae: Planktonic [ ] Filamentous [ ] Macroalgae [ ]

Floating: Free-floating [ ] Floating with roots [ ]

Emergent: In water [ ] Above shoreline [ ]

Submergent: All under water [ ] Parts standing above surface [ ] Marginal [ ]

Coverage: Throughout [ ] Along edges [ ]

Estimate coverage percentage:

Species:

III. Treatment History and Results

Species controlled (same or different?)

When and how often?

Describe method(s), control agents, and results?

IV. Recommendations:

A. Method: Mechanical [ ] Chemical [ ] Biological [ ] Other (specify) [ ]

B. Control agent (adjuvant if necessary)

C. Recommended timing

D. Recommended monitoring

E. Permits required

Appendix III

Request for Permission to Use Toxic Materials for Aquatic Life Management Purposes

MARYLAND DEPARTMENT OF THE ENVIRONMENT
1800 Washington Blvd. ● Baltimore Maryland 21230
(410) 537-3000 ● 1-800-633-6101 ● http://www.mde.state.md.us

REQUEST FOR PERMISSION TO USE TOXIC MATERIALS FOR AQUATIC LIFE MANAGEMENT PURPOSES	When Completed, Mail to: * Maryland Department of the Environment Water Management Administration Industrial Permits Division 1800 Washington Blvd. Baltimore, MD. 21230
Toxic Materials Permit (TMP) Project Number:	*Except for requests to control Phragmites sp. with Glyphosate, which should be submitted directly to: Maryland Department of Natural Resources Environmental Review Unit Tawes State Office Bldg., 580 Taylor Avenue, B-3 Annapolis, MD. 21401

A. PERSON REQUESTING PERMIT
NAME: ____________________
ADDRESS: ____________________
____
DAYTIME PHONE: ____________________

B. PROJECT PURPOSE
[ ] Maintenance of surface flow conveyance
[ ] Right-of-way maintenance
[ ] Mosquito control
[ ] Wildlife management – specify:
____
[ ] Aesthetic improvements
[ ] Fisheries management – specify:
____
[ ] Other – specify:
____

C. TARGETED SPECIES TYPE
[ ] Submerged aquatic vegetation - specify:____________________
[ ] Algae
[ ] Emergent vegetation – specify:
____
[ ] *Phragmites sp.* (See Section F. for General Permit conditions)
[ ] Mosquitoes
[ ] Finfish – specify:
____
[ ] Other – specify:
____

D. INDIVIDUAL WHO WILL SUPERVISE APPLICATION:
NAME: ____________________
TITLE: ____________________
ADDRESS: ____________________
____

E. PROPOSED BEST MANAGEMENT PRACTICES AND IMPACT MINIMIZATION MEASURES
[ ] Markers to delineate application area
[ ] Pond drawdown
[ ] Prevention of pond discharge following application - specify duration:____________________
[ ] Application at slack tide
[ ] Time-of-year restrictions – specify:
____
[ ] Survey of species listed by the State as endangered, threatened, or in need of conservation
[ ] Mechanical harvesting of nuisance species where feasible
[ ] Use of nontoxic dyes for algae and submerged aquatic plant control when feasible
[ ] Removal of dead fish resulting from the application
[ ] Other – specify:____________________

F. *PHRAGMITES SP.* CONTROL with GLYPHOSATE
[ ] Management plan ** - (Briefly specify on the bottom of this sheet or an attachment the schedule and proposed elements of the plan, which may include controlled burns, changes in hydrology, follow-up treatments, re-vegetation with preferred species.)

[ ] Review conducted for species listed by the State as being endangered, threatened, or in need of conservation **

**The Department of Natural Resources (DNR) must approve the plan prior to issuance. The species review (shaded block) must be completed by DNR. Upon completion of their review, DNR will forward their response and the application to MDE to complete the TMP process

Form Number MDE/WMA/PER.015
Revision Date June 20, 2002
TTY Users 1-800-735-2258

1 of 2

Recycled Paper

MARYLAND DEPARTMENT OF THE ENVIRONMENT
1800 Washington Blvd. ● Baltimore Maryland 21230
(410) 537-3000 ● 1-800-633-6101 ● http://www.mde.state.md.us

G. PROPOSED DATE (S) OF TREATMENT

____

____

H. NUMBER OF TREATMENTS: __________

I. PROJECT AREA DESCRIPTION

Street Address & Zip Code of Project

____

____

Name of water area______________
Receiving waterway______________
County______________
Nearest town______________
ADC map coordinates ______________
(Please provide a vicinity map that accurately shows the treatment area)
Size of project area (square feet or acres)

____

Depth of water______________

J. USE OF WATER AREA

[ ] Public water supply
[ ] Livestock water supply
[ ] Recreational
[ ] Commercial finfish
[ ] Wildfowl management
[ ] Industrial water supply
[ ] Irrigation water
[ ] Sport fishing
[ ] Oysters, clams, crabs
[ ] Fur bearers
[ ] Other – specify:

____

K. TOXIC MATERIAL PROPOSED TO BE USED

Trade Name: ______________
Manufacturer: ______________
Active Ingredient: ______________
Formulation (pellets, liquid, emulsion): ______

____

Percent Active Material: ______________
Application Method: ______________

Note: Activities which result in the fill or disturbance of non-tidal wetland areas and their 25-foot buffer areas through the movement of soil, changes in hydrology, or destruction of vegetation may require a Nontidal Wetlands and Waterways Permit from the Department of the Environment (COMAR 26.23). Disturbances in tidal wetland areas may require a Tidal Wetlands License from the Department of the Environment (COMAR 26.24). State agencies must insure that all actions, including permit actions, carried out by them do not jeopardize the continued existence of species which are listed by the State as endangered, threatened, or in need of conservation (DNR Statute 10-2A-04).

MARYLAND DEPARTMENT OF NATURAL RESOURCES REVIEW

[ ] No objection [ ] No objection with conditions

[ ] Need additional information [ ] Objection

Comments: ____

____

____

____

Signature: ____

Form Number MDE/WMA/PER.015
Revision Date June 20, 2002
TTY Users 1-800-735-2258

2 of 2

Recycled Paper

Appendix IV
Useful Conversions

Table 1. Conversion factors

1 acre	43,560 square feet	
1 acre-foot	43,560 cubic feet	325,850 gallons
1 acre-foot of water	2,718,144 pounds	
1 acre-foot of water per day	226.3 gallons per minute	
1 acre-inch of water per day	18.9 gallons per minute	
1 acre-inch of water per hour	452.7 gallons per minute	
1 second foot of water	448.8 gallons per minute	
1 cubic foot of water per second	448.8 gallons per minute	
1 cubic foot of water	62.4 pounds	
1 gallon of water	8.34 pounds	3,785 grams
1 liter of water	1,000 grams	
1 fluid ounce	29.57 grams	1.043 ounces
1 grain per gallon	17.1 milligrams per liter	
1 milliliter of water	1 gram	
1 cubic meter of water	1 metric ton	
1 quart of water	946 grams	
1 teaspoon	4.9 milliliters	
1 tablespoon	14.8 milliliters	
1 cup	8 fluid ounces	
1 foot of water	0.43 pounds per square inch	0.88 inches of mercury (HG)
1 hectare	10,000 square meters	2.47 acres
1 acre	4,048 square meters	

Table 2. Weight Conversions

			To		
From	gm	kg	gr	oz	lb
gm	1	0.001	15.43	0.0353	0.0022
kg	1000	1	1.54x104	35.27	2.205
gr	0.0648	6.48×10^{-5}	1	0.0023	1.43×10^{-4}
oz	28.35	0.0284	437.5	1	0.0625
lb	453.6	0.4536	7000	16	1

gm = gram; kg = kilogram; gr = grain; oz = ounce; lb = pound

Table 3. Length Conversions

From	cm	m	To in	ft	yd
cm	1	0.01	0.3937	0.0328	0.0109
m	100	1	39.37	3.281	1.0936
in	2.540	0.0254	1	0.0833	0.0278
ft	30.48	0.3048	12	1	0.3333
yd	91.44	0.9411	36	3	1

cm = centimeter; m = meter; in = inches; ft = foot; yd = yard

Table 4. Volume Conversions

From	cm^3	liter	m^3	in^3	To ft^3	fl. oz.	fl. pt.	fl. qt.	gal
cm^3	1	0.001	$1x10^{-6}$	0.0610	$3.53x10^{-5}$	0.0338	0.00211	0.00106	$2.64x10^{-4}$
liter	1000	1	0.001	60.98	0.0353	33.81	2.113	1.057	0.2642
m^3	$1x10^6$	1000	1	6.1x104	5.31	$3.38x10^4$	2113	1,057	264.2
in^3	16.39	0.0164	$1.64x10^{-5}$	1	$5.79x10^{-4}$	0.5541	0.0346	0.0173	264.2
ft^3	$2.81x10^4$	28.32	0.0283	1728	1	957.5	59.84	29.92	7.481
fl. oz.	29.57	0.0296	$2.96x10^{-5}$	1.805	0.00104	1	0.0625	0.0313	0.0078
fl. pt.	473.2	0.4732	$4.73x10^{-4}$	28.88	0.0167	16	1	0.5000	0.1250
fl.qt.	946.4	0.9463	$9.46x10^{-4}$	57.75	0.0334	32	2	1	0.2500
gal	3785	3.785	0.0038	231.0	0.1337	128	8	4	1

cm^3 = cubic centimeter; m^3 = cubic meter; in^3 = cubic inch; ft^3 = cubic foot; fl.oz. = fluid ounce; fl. pt. = fluid pint; fl. qt. = fluid quart; gal = gallon

Table 5. Speed

Factor	Multiply by	To get
Miles per hour	1.467	Feet per second
	1.6093	Kilometers per hour
	26.8217	Meters per minute
	29.3333	Yards per minute
	88.0	Feet per minute
Miles per minute	26.82	Meters per second
Feet per minute	0.01136	Miles per hour
	0.01667	Feet per second
	0.01829	Kilometers per hour
	0.3048	Meters per minute
	0.3333	Yards per minute
	60.0	Feet per hour

Table 6. Parts per Million

Factor	Multiply by	To get
Parts per million (ppm)	0.0001	Percent
	0.001	Liter per cubic meter
	0.001	Grams per liter
	0.001	Milliliters per liter
	0.013	Ounces per 100 gallons water
	0.0584	Grain per US gallon
	0.3295	Gallons per acre-foot water
	1.0	Milligrams per liter
	1.0	Milligrams per kilogram
	1.0	Milligrams per cubic meter
	2.7181	Pounds per acre-feet water
	8.345	Pounds per million gallons water