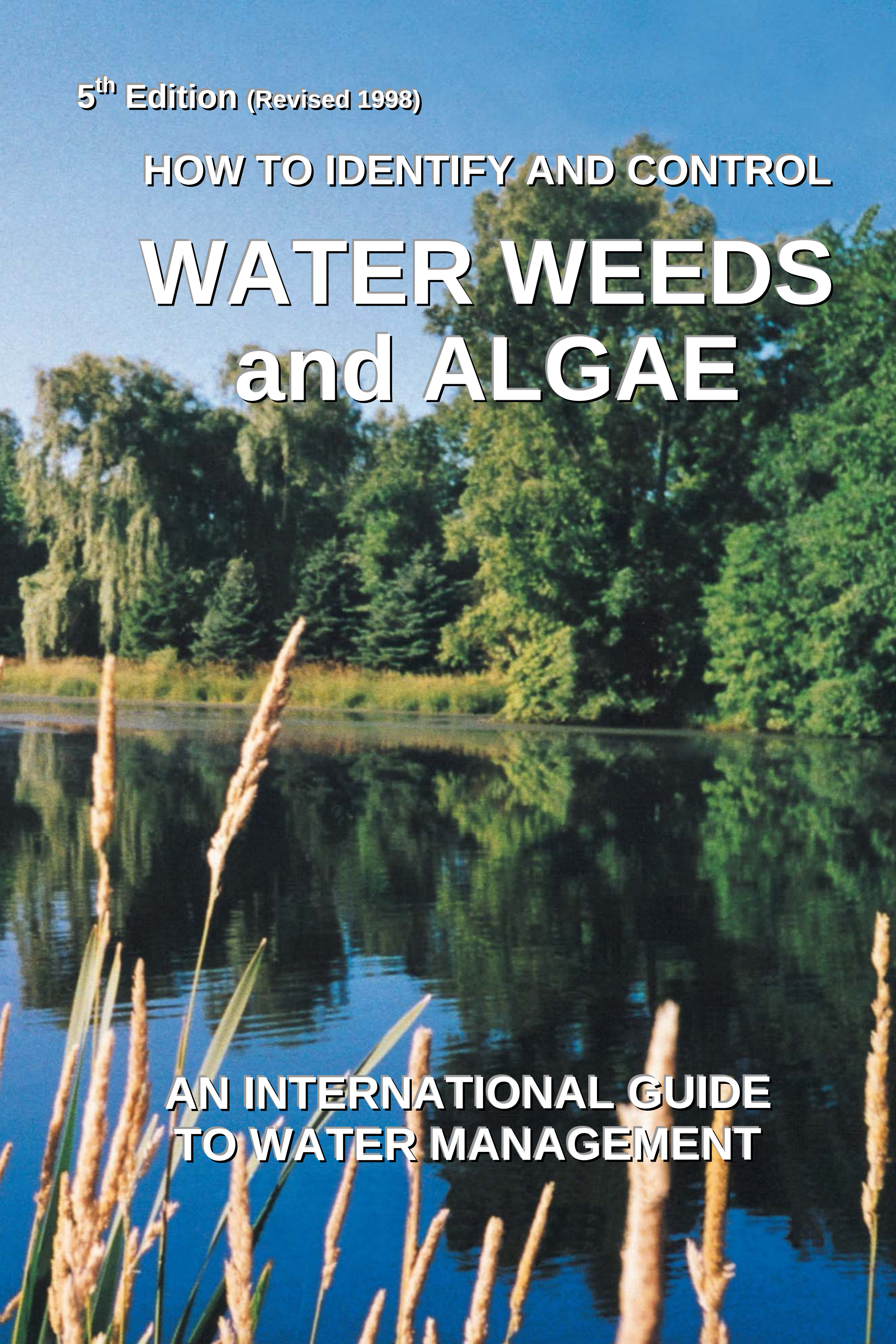
5th Edition (Revised 1998)

HOW TO IDENTIFY AND CONTROL

WATER WEEDS and ALGAE



AN INTERNATIONAL GUIDE TO WATER MANAGEMENT

EDITOR'S NOTE

Worldwide demands are being placed upon freshwater supplies as a prerequisite to expanding real estate, industrial and agricultural development. Economic growth in many areas is dependent upon water of suitable quality and quantity for drinking, household use, irrigation, stock watering, hydroelectric power generation, industrial cooling, transportation, waste disposal and/or aquaculture. After basic demands are met for subsistence and economic development, interest in water resources for recreation and leisure becomes increasingly important.

Multiple use of limited water supplies requires planning and cooperation between users and water managers. As a common resource utilized for diverse purposes, water is readily subject to degradation. A major threat is the increasing fertility of water resulting from nutrients entering by way of agricultural run-off and wastewater discharge. These fertile waters support luxuriant growth of aquatic vegetation that interfere with intended uses. Thus, aquatic weed and algae growth can actually threaten the livelihood and future economic development of an area.

International cooperation to further develop and implement aquatic plant control technologies needs to be coordinated with efforts to educate the public on matters of water quality protection and management. Of significant concern is the accidental and/or intentional transplanting of exotic vegetation into new areas. These exotic species often have the ability to out-compete native plants and grow to nuisance proportion. Without natural enemies, they severely upset the balance of the aquatic ecosystem.

Applied Biochemists welcomes this opportunity to share our aquatic weed control technology and water management expertise with you. We encourage your inquiries and will make every effort to provide you with professional assistance.

How to Identify and Control WATER WEEDS and ALGAE

Technical Editing: James C. Schmidt and James R. Kannenberg
Layout and Design: Donna Bradham
Library of Congress Catalog Card No. 82-84761

5th Edition, Revised 1998

FOREWORD

The recommendations contained in this book are based upon decades of research in aquatic plant control and water management by industry, universities and government agencies. The methods described within have proven successful in thirty years of professional, commercial application and consulting work by Marine Biochemists plus fifty years of laboratory and field work by Applied Biochemists.

Environmental and human safety, economics and effectiveness were primary objectives in the preparation of this manuscript. Both Applied Biochemists and Marine Biochemists are dedicated to promoting sound water management approaches. It is our goal to help enhance and preserve the recreational, aesthetic and economic value of the world's water resources. This book is an educational step toward that objective.

The editors of this edition acknowledge and thank the following staff members for their valuable assistance in writing, updating, proof-reading, designing and contributing their talents to this book: Sarah Burris, John Cortell, Harry Knight, Lynn Mininger, Bill Ratajczyk, Brian Suffern, Bill Thomas and Paul Westcott. Special appreciation goes to Brad Howell, our Division President, for his leadership and support.

Created and Produced by:

APPLIED BIOCHEMISTS
A division of AdvantisTechnologies, Inc.
W175 N11163 Stonewood Drive, Suite 234
Germantown, WI 53218
262-255-4449
TOLL FREE 1-800-558-5106
FAX (262) 255-4268

Web site address: www.appliedbiochemists.com
E-mail address: info@appliedbiochemists.com

TABLE OF CONTENTS

INTRODUCTION

This book is intended for use by government, commercial and private concerns responsible for maintaining the recreational, aesthetic and functional value of water resources. The following groups will gain useful knowledge on controlling aquatic vegetation as well as protecting and improving water quality: **lake property owners; private pond owners; park and golf course superintendents; commercial applicators; campgrounds; resorts; fishing clubs; sanitary districts; water utilities; irrigation and drainage districts; industries; real estate developers; landscapers; fish farmers; and aquaculturists.**

The main text of 'How To Identify And Control Water Weeds And Algae' provides a comprehensive look at aquatic vegetation problems and control measures. This section begins with a historical review followed by a close examination of difficulties associated with excessive growth by various water user groups. Numerous control alternatives are discussed which highlight the benefits and disadvantages of each method.

Step-by-step instructions are provided for controlling undesirable vegetation growth with aquatic herbicides and algaecides. A detailed section on plant identification includes pictures, written descriptions and distribution maps of some of the most troublesome species. Recommended controls and alternatives are provided for each. Directions are given for determining size of treatment area, choosing the best product(s) and calculating dosages. Choice and operation of application equipment are discussed, followed by informative tips on application techniques and safety. A follow-up section assists with developing a maintenance program and answers post-treatment questions.

The remainder of this book focuses on those aspects of lake and pond management that will aid in understanding, preventing, and correcting water quality problems. Guidelines are provided on pond construction, nutrient abatement and reduction, aeration and watershed protection. Suggestions and solutions are given for some common as well as unusual problems. Fish management considerations are presented in an understandable format.

The Appendix provides specific information on products, water use restrictions, dosage calculations and irrigation/flowing water treatment guide-lines. Chemical, biological and botanical terms are defined in the Glossary at the back of the book, and topics are indexed for convenient referencing.

Lake on cover before weed control.

HISTORICAL PERSPECTIVE

Historically, it is doubtful that aquatic weeds and algae presented much of a problem to developing civilizations in areas of the world where water resources were abundant. The demand for clean and open water suitable for transportation, drinking supplies, mills, irrigation and stock watering increased with population and development. Corresponding with this growth were man-made alterations on the land and in waterways that favored increased aquatic plant growth. The introduction of exotic (foreign) species of aquatic vegetation compounded this problem, as many of these plants had the ability to out-compete native vegetation. Few tools, other than manual labor, were available to assist in control efforts. This same scenario repeats itself today in developing countries.

Dr. Bernard P. Domogalla, the pioneer in the field of aquatic vegetation control, was the first commercial applicator of formulated chemicals. He is shown here (third from right) applying Cutrine on Lake Muna in South America – 1958.

In the early 1900's, it was discovered that copper sulfate could be used to inhibit algae growth. Similarly, in the 1920's, sodium arsenite was adopted for use as an aquatic herbicide to kill rooted vegetation.

Advancements in aquatic vegetation control technology developed slowly. First to make major breakthroughs in this science was Dr. Bernard Domogalla, a researcher with the Wisconsin State Laboratory of Hygiene. Unimpressed with the results of copper sulfate treatments and concerned about the adverse environmental effects of copper build-up in the bottom sediments, he formulated a chelated (chemically locked in) copper compound. The product proved to be far superior to copper sulfate in that it provided a longer contact (killing) time due to its stability in alkaline (hard) water. Longer lasting control with lower copper dosages and less frequent applications proved to be direct benefits. The product was patented and named **"Cutrine®"**.

Since the early 1960's, aquatic biologists, biochemists and other scientists have developed lower risk and more effective herbicides to replace sodium arsenite, which was also shown to build up in bottom sediments. Today's products are thoroughly screened and tested by manufacturers, university researchers and governmental agencies before they are registered and allowed for use in the aquatic environment.

It is everyone's responsibility to utilize these products in accordance with their label directions and precautions. The indiscriminate use of compounds **not** approved and labeled for aquatic vegetation control **must** be curtailed. Similarly, products that place extreme use restrictions on our waterways should be used only on a very selective basis.

Aquatic vegetation, interfering with water flow in irrigation and drainage canals, is a worldwide problem. Here, Cutrine-Plus is applied by helicopter to eliminate nuisance growth.

RECENT DEVELOPMENTS

Since Dr. Domogalla's retirement in 1964 and death in 1969, Applied Biochemists has maintained a continuing research program dedicated to improving **Cutrine**. This produced improvement patents in 1970, 1972, 1976; and in 1982, a new patent was granted for **Cutrine-Plus®**.

Today, **Cutrine-Plus** is rapidly supplanting copper sulfate in the knowledgeable water management community. This more concentrated product offers greater stability, contains no sulfates, virtually eliminates the danger of equipment corrosion, and causes no harm to non-target aquatic organisms.

Federal registrations have been obtained for the use of **Cutrine-Plus** in irrigation systems, flowing water, drinking water supplies, and in tank mixes with several aquatic herbicides including the patented **Cutrine-Plus** : diquat dibromide combination. **Cutrine-Plus** has also shown herbicidal effectiveness by itself against several noxious weed species including Hydrilla.

Applied Biochemists was purchased by Laporte, Inc. in 1989. This provided the opportunity to expand their product line and explore new technologies within the aquatic plant management industry.

Aquashade, Inc. was acquired in 1992 to add its patented growth control product to the Applied Biochemists' line. **AQUASHADE®**, a blend of acid blue and yellow dyes, absorbs portions of the light spectrum critical to algae and aquatic plant photosynthesis. **Aquashade** complements other Applied Biochemists' products by providing the maintenance control desired in many aquatic systems.

Applying Aquashade from shore.

Clearigate®, an innovative aquatic herbicide/algaecide, was developed to meet the environmental and economic demands placed upon Irrigation Districts to provide unimpeded water flow without imposing water use restrictions. Proven aquatic vegetation control through the use of this product has achieved this goal. Ongoing evaluation and development of **Clearigate** since 1992 and subsequent EPA registration in 1996 makes this valuable, effective tool commercially available to the industry for operational use.

Marketing agreements for additional aquatic products such as the private label **Navigate®** (a 2,4-D granular formulation), expanded research and development, and the building of a knowledgeable, dedicated technical staff have contributed to Applied Biochemists' recognition as an industry leader. Recent efforts include: finding safer alternative products to replace older, high risk chemicals; improving upon packaging and application delivery systems, and seeking better utilization of all practical technologies (Integrated Pest Management) towards solving algae and aquatic plant problems.

AQUATIC PLANT PROBLEMS

A wide range of aquatic plants can be found growing in, on, and around a body of water. Based upon their various adaptations, some will be found rooted in swiftly flowing streams while others can only survive in placid, stagnant ponds. Within a natural, well-balanced system, these plants provide food and cover for fish, waterfowl and aquatic invertebrates. They produce oxygen, plus help to stabilize bottom sediments.

Like terrestrial plants, aquatic vegetation requires a carbon source, sunlight, and nutrients. Dissolved carbon dioxide, bicarbonates and carbonates, typically quite abundant in water, provide a source of carbon for the growth and food production process known as photosynthesis. The energy driving this process is derived from sunlight. Therefore, the depth of sunlight penetration will limit the depth to which aquatic plants can grow. At the same time, the amount of nutrients available (mainly nitrogen and phosphorous) will limit the quantity of vegetation which can grow.

Aquatic plants derive their nutrients from the sediment and/or the water column. These nutrients are cycled between the sediment and the water on an annual basis. Adding to this nutrient enrichment of lakes and ponds, a process known as eutrophication, are inputs from external sources. Nutrients and sediments are contributed by man's agricultural, domestic and industrial activities through sources such as cropland and feedlot run-off, factory and cannery effluents, domestic waste discharges, construction site erosion, lawn and garden fertilizer run-off and septic tank leachate. The most noticeable symptom resulting from eutrophication is the development of prolific aquatic plant growth.

As nutrient concentrations increase, aquatic vegetation growth can become a serious problem in lakes and ponds.

The point at which aquatic vegetation becomes a nuisance is closely associated with the primary uses of a body of water. By common usage, all aquatic growth is often clumped under the general heading "weeds". A "weed" has been defined in various ways, depending upon the "eye of the beholder". A simple definition is a "plant growing out of place". A more optimistic view is "a plant whose true value has not been realized".

For the purposes of this text, an aquatic plant problem is defined as "undesirable plants that grow so profusely as to crowd out more desirable growth or detract in some way from the usefulness, value, and/or appearance of an area". Therefore, overabundant vegetation that adversely affects aquatic life; impedes industrial, agricultural or domestic water use; interferes with recreational activities and/or destroys aesthetic values, all fall under this definition.

A look at various water-use sites and their specific problems gives some indication of both the economic and environmental impact associated with aquatic plant growth. The degree of control desired will be greatly influenced by these water uses.

Aquatic plants can interfere with many lake and pond uses.

LAKES

The definition of what constitutes a lake varies from region to region, but a general guide is that a lake is any body of water with a surface area of 5 acres or greater. Lakes can be naturally occurring or man-made. Types of naturally occurring lakes include: seepage lakes fed by rainfall, groundwater and limited runoff from land (no stream outlet present); groundwater drainage lakes fed by rainfall, groundwater and limited runoff from land (stream outlet present); and drainage lakes fed by streams, rainfall, groundwater and runoff from land (stream outlet present). Man-made lakes typically are impoundments created by the damming of a stream. This type also has a stream outlet. Lakes can be of variable depths with shallower lakes typically displaying greater aquatic plant growth potential due to increased littoral zones. Littoral zones are areas of lake bottom where sufficient amounts of sunlight can penetrate the water column to support aquatic plant growth. Littoral zones are usually limited to shoreline areas, but may extend to many regions of a lake depending upon the topography of the bottom.

Increasing development of lakeshore areas and intensive recreational-use pressure being placed upon these resources have dictated the need for developing responsible water management programs. Aquatic plants, which had previously grown in unused or undeveloped areas, suddenly present a problem to recreational users and riparian owners. Fouled outboard motor props, snagged fishing lines, a declining fishery, uninviting swimming conditions and falling property values are a few of the problems associated with prolific aquatic growth. Symptomatic control is necessary until more permanent solutions can be researched, financed and implemented.

DRINKING WATER RESERVOIRS

Drinking water reservoirs are a vital component of many populated areas. They are typically designed by damming an existing river in a valley or similar basin. The impoundment floods the basin allowing large amounts of water to be held in reserve for nearby or distant populations. Many different variables can affect the quality of the reserved water as it awaits delivery and ultimate use. Fluctuating water levels, fluctuating water temperatures, stagnation, nutrient influxes from non-point source pollution (i.e. fertilizer or agricultural runoff), as well as other factors can have a negative impact on these waters.

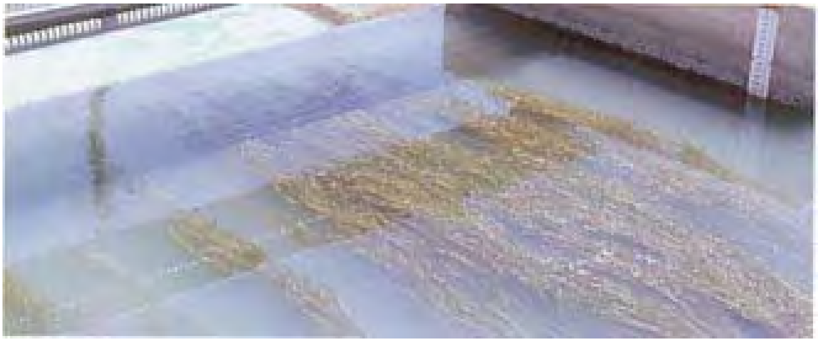
A common natural “contaminant” to these surface water drinking supplies is algae. Problems associated with this growth include discoloration, foul odors, unpleasant tastes and clogged filters. Shortened filter runs requiring frequent backwashes reduce the efficiency of water treatment plants, thus raising the cost of water to the consumer. Chlorinating to remove algae is costly, as is carbon filtration to remove off flavors and odors. In addition, there is evidence that the reaction of chlorine with algae can form trihalomethanes (THM's), suspected carcinogens. Treatment for algal control within the reservoir itself is often the most economical and effective means of eliminating these problems.

IRRIGATION & DRAINAGE SYSTEMS

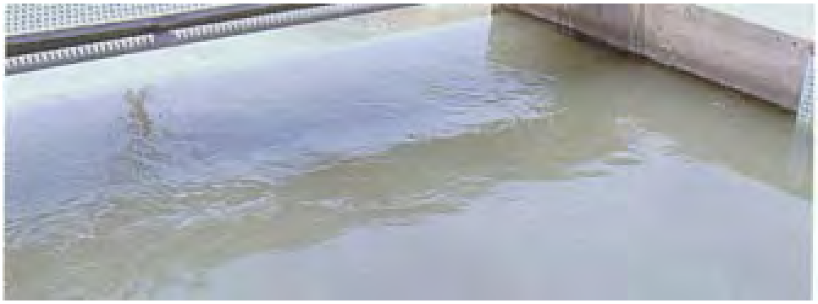
Irrigation has been used since ancient times as a means for civilizations to grow food and prosper within geographic areas which would not typically support populations. Expansion of irrigation in today's world allows agricultural crops to be grown in extensive, fertile, arid regions and golf courses to be developed like oases in the desert. This same efficient transport of water has encouraged the growth of cities in previously desolate areas. Efficient movement of water is critical to the survival and economic growth of these regions.

Surface water drainage systems are critical to many developed areas where there are high groundwater tables, limited relief, abundant precipitation, and/or nearby waterways prone to flooding. Drainage of wetlands and floodplains in the past has left many developed areas dependent upon an efficient network of ditches and canals to take water away. Failure of these systems can cause significant economic loss from flooding.

Aquatic vegetation can severely impede water flow in both irrigation and drainage systems. Reduced flow to irrigated regions can threaten agricultural production by reducing yields or causing crop loss. The damming effect of aquatic plants in drainage ditches increases the threat of flooding in areas dependent upon such systems.



Control structure before Clearigate treatment.



Control structure after Clearigate treatment.

Secondary effects from aquatic plants in flowing water systems include clogging of control gates, distribution lines, water intakes, pump impellers, sprinkler heads and other associated equipment. Stagnation from reduced flow causes higher water temperatures, increased silt deposition, higher evaporation rates and seepage loss. The impounding effect at culverts and bridges can result in washed out or eroded roadways and accesses.

Irrigation and drainage systems are often managed by special units of government or taxing authorities called "Districts". Boundaries are often based upon topography, direction of water flow, network development and water rights, rather than political boundaries. Such Districts are responsible for the maintenance of these systems, including aquatic plant management. See Appendix G, pages 114-117, for treatment guidelines.

WASTEWATER PONDS

Wastewater ponds (sewage stabilization and retention ponds) are essential for the processing of nutrient-rich effluent wastes of civilization and agricultural stock. The complex series of interaction of microorganisms and the exposure to sunlight and atmospheric gas exchange all play an important part in the successful degradation of these wastes. The bound nutrients initially present and the subsequent release of additional nutrients through organic decay can cause severe overpopulation and/or fluctuations in aquatic species present.

Aquatic plants can be a friend or foe in sewage stabilization and retention ponds. Balanced populations serve a function in nutrient removal and oxygenation. However, severe algal blooms, common to these effluent waters, can create serious water quality problems. Violations of discharge standards that can be directly attributed to excess algal growth often occur. These can include exceeding limits for suspended solids, BOD, and pH within discharge water. Rooted and floating plants within lagoons can impair clarification, settling and water flow, plus reduce holding capacity. Aquatic plant management is required to keep these systems operating legally and efficiently.

AQUASCAPES (RE-CIRCULATING WATER SYSTEMS)

Aquascapes, man-made decorative systems for retaining and re-circulating water, have become quite popular around hotels, and residential and office complexes. Ranging in size from a few thousand to several million gallons of water, they may be as simple as a small ornamental pond or as elaborate as a series of ponds expanding throughout an entire complex. They may encompass streams, waterfalls, fountains, multiple reflective pools and other aesthetic features. Surrounding topography may consist of highly managed turf, naturally growing plant communities, desertscapes, or a variety of other landscape scenarios. Retention time of the water (the amount of time a given amount of water remains within a system) may be extremely long with the only water exchange coming from make-up water for evaporation effects, to extremely short with constant exchange of water coming from incoming fresh water to replace water lost by evaporation, outflow, leakage, etc.

Aquascapes provide a unique habitat for aquatic vegetation growth and, as such, may develop aquatic growth concerns. Algae growing on the walls and bottoms or suspended within the water are the most pre-dominant problems. It is sometimes assumed that these systems can be managed similarly to swimming pools. However, their volume and design often make this cost prohibitive. Furthermore, when fish or potted aquatic plants are added, many pool chemicals could negatively affect desired aquatic life. A maintenance program must be designed to preserve the clarity and quality of water desired without impacting beneficial components of the system.

INDUSTRIAL AND OFFICE PARK PONDS

Many modern industrial facilities and office complexes are dependent upon ponds for a variety of reasons. These ponds may be utilized for cooling water, fire protection, storm water retention, and/or grounds irrigation. Some were constructed strictly for aesthetic purposes. Sites such as these may have many different aquatic problems depending on their location and principal function. These situations may be nothing more than an aesthetic concern or a complete environmental problem with great economic impact.

Aesthetic problems may seem minor, but the public image of a complex or company is of vital concern to owners and the surrounding community. This image can relate directly to the self-esteem of the community as a whole. In some cases, the property values within an area may be positively or negatively influenced by the outward appearance of nearby industry.

The situation becomes more critical when aquatic plants impede the function of the facility. This occurs when weeds clog fire protection ponds and block water intakes leading to possible safety problems and/or costly pump failures. Another critical situation is when planktonic algal blooms raise total suspended solids, BOD levels, and/or pH levels beyond environmental permit limits.

Regardless of the purpose that an industrial or office park pond serves, excessive aquatic plant growth rarely can be tolerated. Proper management of aquatic plant populations can, however, maintain both function and appearance.

SWIMMING PONDS, BEACH AREAS AND BOAT RAMPS

From the swimming holes of old to the cherished family outings at the lake, water has been an integral part of recreation in modern society. Growing populations have, however, put increased pressure on swimming and boat launching areas. Increased use of boat launching areas has also brought in new aquatic species not native to many lakes and ponds. The spread of these exotic species as well as increased native aquatic growth due to abundant nutrient loads has become a very visible concern at these public use areas.

Weeds left on boat trailers can spread exotic species.

Thus, intensive control of aquatic plants within these areas used exclusively for swimming or boat launching is required. Safety and liability are primary considerations here, since algae can create slippery, hazardous conditions on boat ramps. Heavy growth within swimming areas can impede or obscure swimmers. Odors, insect pests and the negative perception of "unclean" water makes these areas uninviting, unsafe, and under-utilized if control measures are not implemented.

GOLF COURSE AND PARK PONDS

Water has historically been an important component of the aesthetics and management of golf courses and parks. The diverse terrains of many golf courses rely on ponds and waterways to increase course challenge as well as provide vital water sources for fairways and greens. Parks and parkways incorporate ponds and lagoons to provide reflective qualities and waterfowl habitats important to their patrons. Highly managed terrain and other turf management practices surrounding these ponds and waterways has in many cases had a negative affect on their general water quality.

Consequently, these shallow water hazards and scenic lagoons located on well-fertilized, manicured golf courses and parkland are prime targets for noxious aquatic plant growth. Drainage and runoff supplying these waterways carry high concentrations of nutrients. Unsightly, overgrown ponds detract from the beauty of a course and may interfere with operation of irrigation systems. Recent emphasis by state and federal agencies has been placed on the development of urban fishing programs within city parks. Shoreline fishing by children and senior citizens is greatly inhibited or curtailed by heavy aquatic growth. Aquatic vegetation control programs should be developed at parks and golf courses to complement grounds management efforts.

STOCK WATERING TANKS & FARM PONDS

Water has always been an essential element in the livestock industry. Beginning with ancient times and exploding into the Americas with the arrival of the cattle trade and dairy industries, quality water supplies for herd use have been a vital factor for industry longevity. Today's standards demand consistent quality water supplies not only to ensure successful herd production, but also to address public health concerns. The very nature of the locale of some of these valuable water supplies lends itself vulnerable to aquatic plant and algal problems. Excessive nutrients from surrounding agriculture and from stock herds themselves can complicate efforts to maintain these quality water sources.

Excessive aquatic plant growth can interfere with livestock water consumption. Subsequent animal health and growth problems may result. In some areas, toxic algae blooms may lead to sickness or death (see pg. 31 "Toxic Algae"). Water tanks located in remote areas are often plagued with plant growth that clogs float valves. Water overflow can wash out the base of the tank and create inaccessible, muddy conditions. It is very important that the control method chosen does not restrict water consumption for excessive periods of time.

FISH PONDS, HATCHERIES AND AQUACULTURE FACILITIES

Whether fish are raised for commercial sale, personal consumption or sport, aquatic plant populations can be managed within a system to optimize fish production. This may range from virtual eradication of growth within cement-lined trout raceways to maintenance of moderate planktonic algal blooms on catfish ponds. A limited amount of underwater cover is desired in warm-water ponds to act as a nursery for young fish, however, too much will lead to stunting of panfish.

Severe algae growth in a Taiwan shrimp pond is examined by a Technical Rep from Applied Biochemists.

Underwater growth and filamentous algae cannot be tolerated at all in commercial ponds, which are harvested by seining. Respiration or die-off and decomposition of large aquatic plant populations during prolonged periods of cloudy weather or under snow-covered ice can critically deplete dissolved oxygen concentrations. Summerkill or winterkill of fish is the result. Some off-flavors in fish flesh have also been attributed to algal growth. In addition, environmental stress caused by excessive plant growth may make fish more prone to disease and parasitic infestation.

AQUATIC PLANT CONTROL METHODS

Waters clogged with aquatic vegetation are usually rendered useless for their intended purposes. Correctional methods are available, but before choosing a technique, consider the following interrelated factors:

1. **What is the intended use of the water?**
   It is usually not necessary to **eliminate** all of the growth, but rather to **control** the vegetation which is creating a nuisance. The degree of aquatic plant control is determined by water use.

2. **How safe is the method?**
   This should not only include human hazards, but also the environmental impacts. Seemingly harmless alterations in the aquatic environment can sometimes result in severe ecological damage such as loss of all fish and plant life.

3. **How effective is the method?**
   Various control methods offer varying degrees of effectiveness. Assess how long it will take to obtain control and how long control will last.

4. **What method is least costly?**
   This question must be judged on a long-term basis. Capital investment and labor must be included in these costs. Safety and effectiveness are also factors to be evaluated.

The following methods have been used as aquatic nuisance control techniques. The advantages and disadvantages of each are discussed.

PHYSICAL REMOVAL

Hand harvesting of aquatic vegetation by pulling, raking, cutting or digging can be accomplished in small shoreline areas. Specialized rakes and cutters have been designed to increase efficiency. Neighborhood youth groups might want to designate a lake or pond "clean-up day" as a community project. Be aware, however, that working underwater is a cumbersome and tiring task, and re-growth from seeds and remaining underground plant parts can be expected.

Fragmented plants, limited maneuverability and high cost are some of the problems associated with mechanical weed harvesting.

MECHANICAL REMOVAL

Specialized mechanical equipment has been developed for both cutting and harvesting (removing) aquatic weed growth. Units range in size from toothed blades which attach to a rowboat up to large harvesters equipped with retrieval and unloading conveyors.

Harvesting facilitates removal of a certain amount of nutrients and organic material from the lake in the form of plant tissue. Unless done intensively, noticeable reduction of nutrient concentrations and sediment build-up will not occur.

Harvesters are sometimes utilized for offshore weed removal, supplementing a chemical treatment program along hard to reach shoreline areas. Another effective approach involves harvesting a week or so prior to chemical treatment. This enhances chemical effectiveness since many plants are quite vulnerable in their active "re-growth" stage.

When harvesting, remove all plant fragments to avoid their re-establishment throughout the lake. Harvesting does have its drawbacks and these must be considered:

- Initial investment is high plus maintenance is expensive.
- Mobility and effectiveness are limited around developed shorelines and over uneven bottoms.
- Hedgerows of weeds, left several feet below the water, can branch out and re-grow at greater densities.
- Several cuttings will be required per season.
- Fragmented plants can establish themselves in new areas.
- Harvested weeds should not be left on shore to dry and hauling can be costly since fresh weeds are quite bulky. (NOTE: Gardeners and farmers will sometimes take aquatic weeds and utilize them for mulch materials.)
- Harvesting is ineffective in removing algae and duckweed.
- Cutting bars can disturb valuable spawning areas.

BIOLOGICAL CONTROLS

Plant consumers (herbivores), microbial bio-augmentation (microorganisms), plant pathogens (diseases) and competitive species are under study as "natural" approaches to controlling noxious vegetation. While some have shown promise, the introduction of exotic organisms carries with it unknown, long-term ecological consequences.

Plant-eating fish such as the **grass carp** or **white amur** (*Ctenopharygodon idella Val.*) have been stocked in lakes, ponds and canals to consume aquatic vegetation. Although banned in most states, sterile (triploid) stocks may be introduced in some areas. Long-term effects upon native fish and plant populations are still unpredictable. Questions exist on suitable stocking rates, competition with game fish and potential for habitat destruction. Feeding by these fish is initially selective. However, as sources of preferred plants become scarce, feeding will continue on other types of growth. This can lead to the eradication of all rooted vegetation, the habitat required by desired game fish species. Furthermore, the short intestine of these fish results in incomplete digestion of plant materials and rapid recycling of nutrients. Algal blooms, not controlled by these fish, can result.

Similarly, **Tilapia** have been stocked in waters to feed upon algae. These fish are highly successful at reproducing in warm waters and have been known to overpopulate. They are sensitive to cold water and do not survive if water temperatures fall below 50°F (10°C). They are not a preferred sport species and are of questionable quality for food.

Microbial bio-augmentation consists of adding concentrated populations of non-pathogenic, naturally-occurring microorganisms and enzymes to accelerate organic decomposition and to either create or augment an essential component of an ecosystem's food web. Specially formulated products contain several different organisms to degrade complex organic materials (bottom "muck"). The byproducts produced (gases) are released to the atmosphere and/or are assimilated into the microorganisms' biomass. Reductions in soluble nutrients and organic soft sediments have been seen in field trials by applicators. Decreased suspended organic solids may also be affected. It is necessary to note that reduction of incoming nutrients through proper watershed management practices (see pg. 105) and installation of sufficient aeration systems are necessary for the overall success of microbial bio-augmentation. Without reducing incoming nutrients, addition of microorganisms will have minimal impact. Many of the microorganisms currently available have cultures that will only function efficiently in aerobic (oxygen present) environments. The use of this method requires careful evaluation of the water body and surrounding terrain as a whole to rectify influences on its ecosystem prior to its implementation.

Insects have been introduced with some success to selectively feed upon aquatic plant populations. Adults and/or larvae of certain moths and weevils, taken from their native areas, have been introduced where exotic plant populations have become established. Some success has been achieved in controlling Water Hyacinth, Eurasian Watermilfoil and Alligatorweed. Various agencies and institutions are currently conducting research on native and exotic species to determine their effectiveness and possible impacts on non-target species. Extreme caution must be taken to ensure these insects will not feed upon native plants or agricultural crops.

Competitive plant species, introduced in some areas in an attempt to overtake existing noxious species, has had limited success. Without control over numerous environmental factors, it is difficult, if not impossible, for man to dictate what should grow where within the aquatic environment. "Aquatic gardening", unlike terrestrial farming, contains too many uncontrolled variables.

Plant diseases or pathogens such as bacteria, viruses, fungi and other microorganisms which host upon aquatic plants are being examined as selective control agents. Isolation and culturing of these organisms must be perfected and their effects upon native aquatic plants, terrestrial species and animals must be carefully looked at before they are "seeded" into new environments.

NOTE: State, Federal and International regulations prohibit and/or regulate the transportation and introduction of exotic organisms discussed above. Consult your local authorities.

HABITAT MANIPULATION

Drawdown or periodic lowering of water levels to expose bottom sediments, where physically possible, is an effective tool for controlling some aquatic weed species. Desiccation (drying-out) of underwater weeds and compaction of bottom mud results. Freezing of the ground during drawdown will also kill the roots and underground stems of certain aquatic plants. Encroachment by emergent shoreline plants, seed survival, and destruction of fish habitat can present a problem if drawdown is improperly timed.

This lake was drawn down for dredging purposes. Such drastic measures may destroy fish populations and habitat plus make way for encroachment by emergent plants.

Dredging has the benefit of removing existing rooted plants and nutrient rich sediments plus increasing water depths. If the bottom is properly contoured, underwater weed growth can be reduced or eliminated. Draglines with clam buckets are used for small pond work. Large hydraulic dredges are employed on large bodies of water. Disposal of spoils presents the biggest problem since water contained in the saturated muck should be prevented from re-entering the watershed. As a result, dredging is very costly.

A dragline equipped with a clam bucket can deepen shoreline areas around ponds. Be sure to remove dredge spoils from the area to prevent them from washing back into the water.

Dilution or flushing a water body with fresh water from a nutrient-free source can aid in lowering nutrient concentrations. As a result, some aquatic plant growth will be reduced. Rooted aquatic plants utilizing nutrients contained in bottom sediments will remain unaffected.

Bottom Barriers made of plastic, rubber, fiberglass screen or nylon are available for placement in beach or shoreline areas or small ponds. They are intended to inhibit or prevent rooted growth within selective areas. They are best installed during pond construction, drawdown, or during periods when growth is not present. Algae and free-floating vegetation are unaffected. Build-up of even slight amounts of sediment on the liner will provide substrate for new growth.

Fertilization of ponds to produce planktonic algal blooms that shade out rooted vegetation and increase fish production is a method commonly used by commercial catfish farmers in the South. Most ponds, however, are fertile enough to support an abundance of life. The addition of more nutrients can compound existing problems by stimulating additional noxious weed and algae growth. Blooms detract from the recreational and aesthetic value of the pond and can create taste and odor problems.

Physical shading of water areas with black plastic sheeting, artificial structures, or overhanging shoreline vegetation has been attempted to inhibit aquatic plant growth. Sheeting makes the water inaccessible for a period of several weeks. Man-made structures and bank vegetation serve only to partially limit light penetration. Shade tolerant aquatic species will still develop.

CHEMICAL SHADING

Shading water areas with soluble dyes to inhibit aquatic plant growth has been done successfully. Specially made aquatic dyes such as **Aquashade** can inhibit plant growth by limiting sunlight penetration to bottom areas where the majority of aquatic growth begins. **Aquashade** works especially well in clear water ponds and lakes with high nutrient levels. It should be noted that soluble dyes have limited effect in waters less than two feet deep.

Aquashade is a blend of blue and yellow dyes scientifically formulated to absorb the wavelengths of light (red-orange and blue-violet) required for aquatic plant and algae growth. This action effectively inhibits photosynthesis in young, bottom growth and may prevent development altogether if applied early enough in the season. Inhibition of planktonic (suspended) algal blooms has also been proven through the use of **Aquashade**. Desirable, floating-leaf plants such as lilies are unaffected by **Aquashade** if they have already surfaced and concentrated product does not contact leaves directly.

Aquashade is the only "colorant" product of its kind that is registered by the U.S. Environmental Protection Agency for aquatic plant growth control. Therefore, it is the only formulation that has gone through the necessary testing to meet these criteria. Aquatic plant growth control claims made by other dye manufacturers are illegal under both Federal EPA regulations and U.S. patent laws. Furthermore, aquatic treatments with non-registered dyes, even as a colorant, are illegal in some states. Environmental and regulatory concerns warrant prudent use of properly labeled aquatic treatment products.

Aquashade dispersing in a pond.

CHEMICAL CONTROL

The use of chemicals is the most common and versatile management strategy for controlling nuisance aquatic plant populations. Chemicals offer longer lasting control than mechanical methods; involve minimal labor and equipment; provide flexibility and predictability; plus, ultimately cost less. From the range of products available, spot control within particular areas or selective control of specific plant species can be achieved. Applications can be made to sites that cannot or might not be reached by other methods. Algaecides and aquatic herbicides will not disrupt the ecological balance and in many cases can be used to restore some balance to a system. Ingredients are non-persistent. They will degrade or become deactivated within a relatively short period of time after controlling target plants. Therefore, no build-up occurs within the fish food chain.

Chemical treatment provides an effective means of controlling nuisance plants.

Products currently allowed for use are somewhat limited due to the stringent government registration process. Millions of dollars and years of research have gone into testing these compounds on a broad spectrum of target and non-target organisms. Evaluations are made not only by the manufacturers themselves, but also by universities, government agencies, private consultants and commercial applicators.

The registration process requires a battery of short-term (acute) and long-term (chronic) testing under a variety of environmental and laboratory conditions. Toxicity to rats, fish, aquatic invertebrates, desirable vegetation (crops, ornamental plants, turf, etc.) and other potentially exposed organisms must be determined. Screening tests and multiple generation studies on test animals are conducted to determine effects on cell function and growth, fetal development and pregnancy. Chemical residues and breakdown products are examined to trace the pathway of the compounds within the environment. Effects from altering water temperature, light intensities, water qualities and other factors are also investigated. Determinations are made as to the application rates and frequencies required to control the target aquatic plant species.

The outcome of this testing is the drafting of a product label designed to provide instructions for applying the product effectively and to help prevent product misuse. Specific directions are provided for handling, application, container storage and disposal, and water use restrictions following application. Use instructions and precautionary wording are clearly stated on the label. Additional product data is available from the manufacturer providing additional insight into product toxicology, environmental effects and use.

Proper use of these products may entail temporary restrictions on use of water for swimming, fish consumption, drinking, irrigation or domestic use. These restrictions vary with the different chemicals used (see pg. 110). Local permits and/or licensing may be required on public waters. Varying water, weather and/or plant growth conditions could interfere with product effectiveness. With proper planning, timing, application and follow-up - safe, effective and economical control of nuisance aquatic plants can be achieved.

There are aquatic herbicides and algaecides available that are specifically labeled for use in lakes, ponds, irrigation and drainage systems, etc.

The following sections of this book provide the step-by-step procedures and information necessary to accomplish the above objectives:

CHEMICAL TREATMENT CONSIDERATIONS

1. **IDENTIFICATION** - See pages 29-75
2. **TREATMENT AREA DETERMINATION** - See pages 76-77
3. **CHEMICAL SELECTION** - See pages 78-79
4. **EQUIPMENT SELECTION** - See pages 80-84
5. **APPLICATION** - See pages 85-88
6. **FOLLOW-UP** - See page 89

STEP #1
PLANT IDENTIFICATION

Identifying the type or species of plant(s) to be controlled is the first step in implementing a management strategy. You may choose to make the identification yourself by using the pictures and descriptions in this book or have the growth examined by a trained biologist. Personnel from Fish and Game, Soil Conservation Service, Department of Natural Resources, etc. may be able to assist. If it is more convenient, a form on page 127 can be sent along with vegetation samples. You will receive a written report on the sample submitted.

Aquatic plants are classified into simplified categories based upon their growth form and location in the environment. The identification section of this book is divided into the following plant groupings:

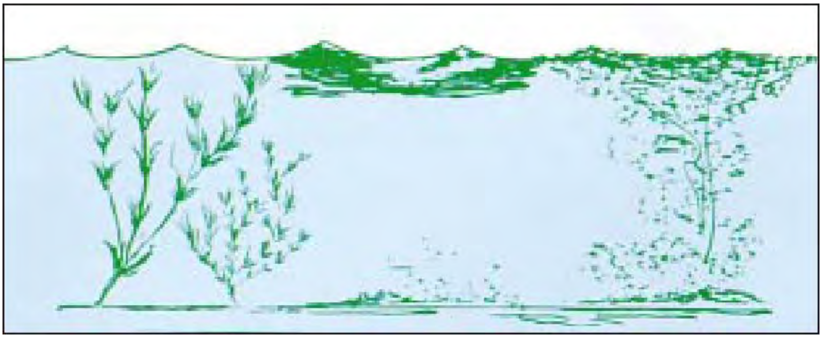
ALGAE (pages 30 to 35)
FLOATING PLANTS (pages 36 to 44)
SUBMERGED PLANTS (pages 45 to 65)
EMERGENT PLANTS (pages 66 to 75)

Become familiar with the definition of each of these groupings in order to determine the section where your plant specimen may be found.

When collecting plants to be identified, note their location in the lake or pond (i.e. submerged, floating, emergent) and refer to the proper section in this book. Use the illustrations, written descriptions and geographical distribution maps to determine species. For algae, determine type (filamentous, planktonic, or attached-erect forms). Take particular note of location and structure of leaves, seeds and flowers when comparing plants to pictures. Noting relative abundance of each type as to whether they are abundant, common or scarce will assist in determining the proper control product(s).

Following is a pictorial guide and written description of aquatic plants commonly found in lakes and ponds. Recommended and alternative chemical choices are given for controlling each type based upon label recommendations and many years of actual field experience. Numerous factors have been considered including human and environmental safety, effectiveness, ease of application, and cost. Only aquatic chemicals properly registered with the U.S. Environmental Protection Agency and the majority of state conservation commissions are recommended. Nevertheless, it is prudent to clear use of any product with your proper government agency before applying.

ALGAE



The algae are primitive plants closely related to the fungi. They exhibit no true leaves, stems or root systems and reproduce by means of spores, cell division or fragmentation. Some 17,400 species of algae have been identified and thousands more probably exist.

These organisms have adapted to many different habitats and exhibit a wide range of characteristics. They can be found in many places from hot springs to glaciers, fresh water to salt water and sandy beaches to rice paddies.

On the following pages nuisance algal growths are classified into 3 general categories: planktonic, filamentous, and attached-erect forms. The use of copper sulfate has not been recommended as research and field usage have shown a high potential for detrimental environmental effects. In certain waters copper sulfate is quite toxic to fish and other organisms. Overuse of this product is common due to its short-term effectiveness. This can result in copper build-up in the sediments leading to a sterile bottom (see Historical Perspective, page 5).

This pond experienced severe problems with filamentous algae (left).

Periodic treatments with Cutrine-Plus control this growth (right).

TOXIC ALGAE

Death and sickness to pets, livestock, wildlife and even man have been attributed to the presence of certain algae, mostly blue-green bloom-forming species, in water supplies. Lethal substances produced by these algae are retained within the cells and released after death (endotoxin) or are secreted from living cells (exotoxin). Much is still left to be learned about the nature and origin of these substances. **It is important that water purification engineers, livestock raisers, wildlife specialists, pond owners and lake property owners are aware of this potential danger.** Many unattended farm ponds and other waters contain some of these toxic forms, posing a threat to human health and the environment. Medical case histories, biologist reports and laboratory tests show some of the possible effects of toxic algae.

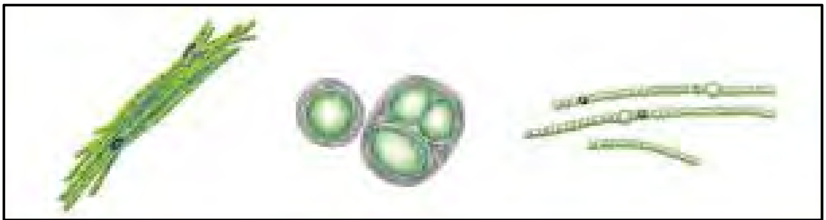
Planktonic ("Pea Soup") Algae.

HUMANS: A list compiled by the U.S. Department of the Interior Federal Water Pollution Control Administration summarizes medical case histories of algal poisonings for a 120 year period. Exposure to and ingestion of algae caused a variety of discomforts including: skin rashes, headaches, nausea, vomiting, diarrhea, fever, muscular pains and eye, nose and throat irritation.

WILDLIFE : Severe ecological disruptions attributed to overabundant toxic algal species have been reported. For example, an Iowa State biologist reporting on an algal bloom on Storm Lake recorded the loss of thousands of Franklin gulls, migratory waterfowl and fish.

LIVESTOCK : The California State Water Resources Control Board states in their Water Quality Criteria Handbook (Second Edition): "From many different parts of the world, including the United States, there have been reports of rapid deaths of a great variety of animals after drinking water containing high concentrations of blue-green algae such as **Microcystis, Aphanizomenon, Nostoc rivulare, Nodularia, Gleotrichia, Gomphosphaeria** and **Anabaena**. Fatal poisonings have occurred among cattle, pigs, sheep, dogs, horses, turkeys, ducks, geese and chickens, and also among experimental animals such as rabbits, rats, guinea pigs and mice. It is believed that such algae may be toxic to all warm-blooded animals."

PLANKTONIC ALGAE - Common genera: Anabaena, Chlorella, Pediastrum, Scenedesmus, Oocystis.



Magnified cells.

TREATMENT TIPS

Usually, the upper 3 to 4 feet of water will require treatment for effective control. At the mercy of wave and current action, planktonic algae will sometimes accumulate along windward shores or in backwater areas, thus reducing the size of the treatment area.

Description: Planktonic algae are microscopic plants, usually suspended in the upper few feet of water, which often reach bloom proportions. Their presence will cause water to appear pea soup green or brownish. Natural die-off may cause summerkill of fish due to oxygen depletion. Some species may be toxic to livestock, wildlife, or man (see page 31) or impart taste and odor problems (page 11).

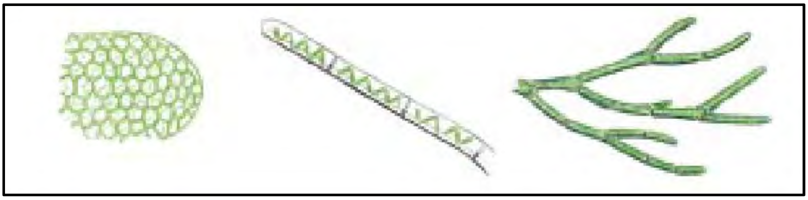
Distribution: Worldwide

NOTE - The above picture was taken at Lake Delavan, WI. Treated for many years with tons of copper sulfate, build-up of copper precipitated in the sediments and shading by the algae bloom prohibited establishment of rooted plant growth, which would have competed for nutrients. Fishing and recreation declined. Effective restoration measures, which included use of **Cutrine** algaecide, have helped to re-establish desirable vegetation and restore recreational value.

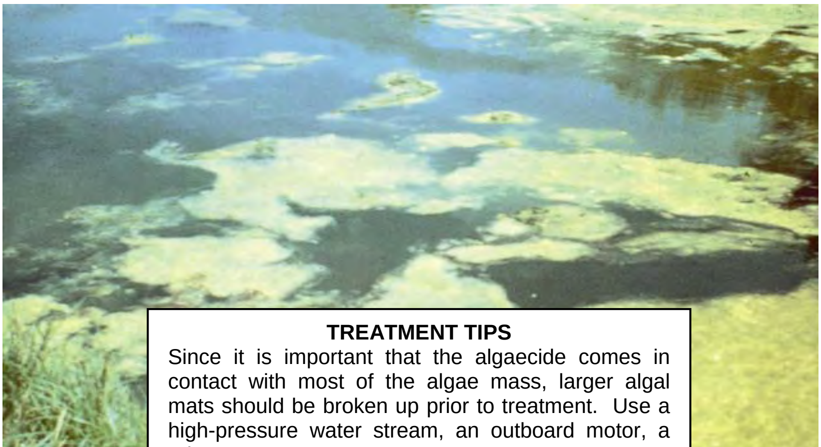
Recommended Control Method: Apply 0.6 gallons of **Cutrine-Plus** per acre-foot of water. Chemical should be diluted at least 20 to 1 to achieve uniform dispersion of algaecide in water. Several treatments may be required for seasonal control.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

FILAMENTOUS ALGAE - Common genera: Spirogyra, Cladophora, Rhizo-clonium, Mougeotia, Zygnema and Hydrodictyon.



Magnified cells.



TREATMENT TIPS

Since it is important that the algaecide comes in contact with most of the algae mass, larger algal mats should be broken up prior to treatment. Use a high-pressure water stream, an outboard motor, a rake or an oar.

Description: Also known as "pond scum" or "moss", filamentous algae forms greenish mats upon the water's surface. This algae usually begins its growth along the edges or bottom of the pond and "mushrooms" to the surface buoyed by the oxygen it has produced. Individual filaments are a series of cells joined end to end which give the thread-like appearance. They also form fur-like growths on bottom logs, rocks and even on the backs of turtles. The texture of these growths may be slimy, cottony or coarse. Common names such as frog spittle and water net have been given to a few forms.

Distribution: Common in its many forms worldwide.

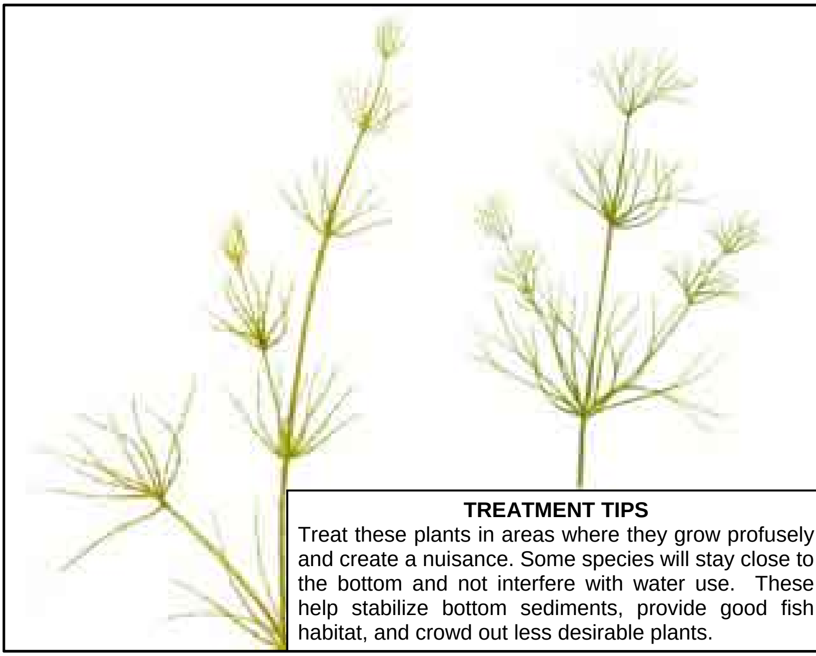
Recommended Control Method: Apply 0.6 gallons of **Cutrine-Plus** per acre-foot of water. Chemical should be diluted at least 9 to 1 to achieve uniform dispersion of algaecide in water. For treatment of bottom growing algae, apply **Cutrine-Plus Granular** at the rate of 60 pounds per acre. Granular can also be used to spot treat localized bottom infestations.

Several total or spot treatments may be required to maintain control during the season. Length of growing season, sunlight, temperature and nutrient concentrations affect the rate of re-growth.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

ATTACHED-ERECT ALGAE (Weed-Like)

CHARA (A) and NITELLA (B) - Common names: Muskgrass, Stonewort.



TREATMENT TIPS

Treat these plants in areas where they grow profusely and create a nuisance. Some species will stay close to the bottom and not interfere with water use. These help stabilize bottom sediments, provide good fish habitat, and crowd out less desirable plants.

Description: These advanced forms of algae, which are gray-green or yellow in appearance, are often mistaken for higher vascular plants. The best way to identify them is by the musky odor and gritty, bristly feel due to calcium deposits on the surface. Leaf-like structures are whorled about the stem at fairly uniform intervals. Chara has a hollow stem. Dense growths, attached but not rooted, may cover entire bottom of pond or lake. Water in vicinity is usually clear.

Distribution: Commonly found in hard water worldwide.

Recommended Control Method: Apply 60 pounds of **Cutrine-Plus Granular** per acre of water. Best treatment results are achieved when plants are young and uncalcified.

OR

Where chara is in water less than 3 feet deep or where growth is near the surface, liquid **Cutrine-Plus** can be used. Apply 1.2 gallons of **Cutrine-Plus** per acre-foot of water. Dilute at least 9 to 1 with water to achieve uniform distribution of chemical.

In hard water, or those with thick infestation, two applications of chemical may be required for control of chara. If not treated early, old growth will become hardened. Additional growth can be suppressed, but older plants may not die and decompose. Treat earlier next year.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

TOLERANT ALGAE

A few forms of algae may be encountered which show some tolerance to control with **Cutrine-Plus** and other chemicals. In these situations, the following recommendations should be attempted to obtain **conditional control:**

"Pads" of Pithophora.

Pithophora is a dark green filamentous algae (also known as horsehair algae). It commonly grows in coarse clumps of tangled filaments resembling pads of steel wool. Individual filaments show extensive branching. Due to its high production of reproductive cells, known as akinetes, growth is quite prolific. Pithophora grows on the bottom and sporadically surfaces.

Lyngbya colonies on water surface.

Lyngbya spp. is a blue-green algae. The species which are particularly troublesome to control are those which grow in colonies forming small spongy masses of mucilage. These blue-green, black or gray clumps made up of thousands of individual cells will lay on the bottom or float to the surface. Because of the protective mucilage, chemical control is difficult.

Conditional Control Alternatives:

for Pithophora

When water temperatures are between 50° F and 60° F, apply 1.2 gallons of **Cutrine**-**Plus** per acre-foot of water followed up to 7 to 10 days later with 60 pounds of Cutrine-**Plus Granular** per surface acre.

For Pithophora or Lyngbya

Tank mix 1 part Reward® to 1 part **Cutrine**-**Plus** and apply at the rate of 2 gallons of mix per acre-foot.

OR

Apply 2.5 to 4.0 gallons of **Clearigate** per acre-foot of water concentrating on littoral/shoreline areas (higher rates for most resistant forms).

OR

Tank mix 2 parts **Cutrine-Plus** to 1 part Hydrothol® 191 and apply at the rate of 1 gallon of mix per acre-foot.

Colonial diatoms on cement bottom.

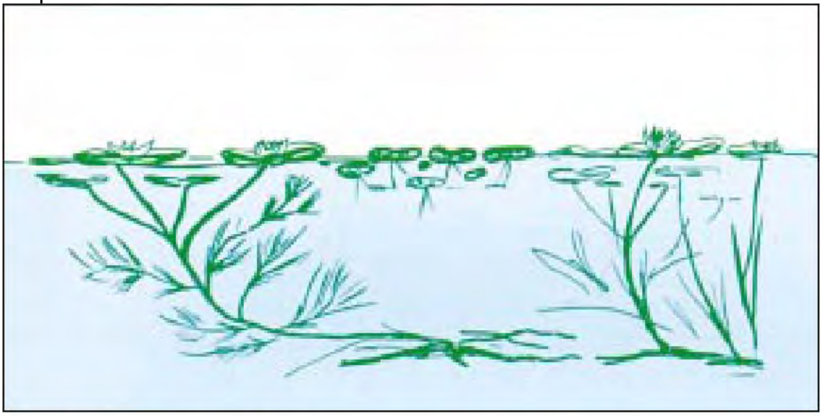
Colonial Diatoms- diatoms are a form of algae characterized by having cell walls made of silica, a mineral substance. Certain species of diatoms grow in colonies, usually on sand or concrete surfaces, and produce gelatinous masses. Generally, these colonies are brown to grayish in color. Effective control has been achieved using **Clearigate** at the rates of 1.8 to 2.7 gallons per acre-foot treating the entire water volume-repeat applications may be needed.

ATTENTION: RECOMMENDATION FACTORS

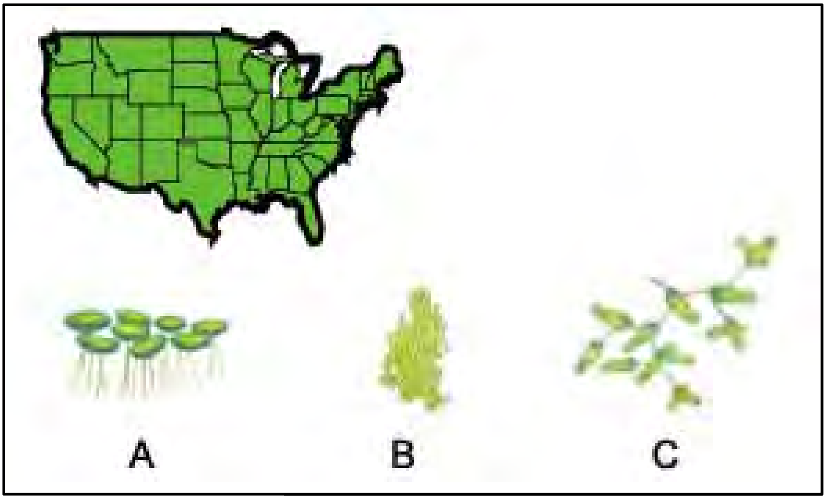
Many factors have been considered in our recommendations such as effectiveness, toxicity, environmental impact, ease of application and economics. Alternative control methods may be necessary due to water use restrictions (see page 110). Plant distribution within the U.S. is shown on shaded maps accompanying weed pictures. Most of these plants, or closely related species, are found worldwide. Trade names mentioned in this book have manufacturer references in Appendix A, pages 107-109. Alternative Control methods are listed alphabetically, not in order of preference.

FLOATING AQUATIC PLANTS

Plants with leaves that float on the surface and are rooted on the bottom are included in this category. Free-floating surface plants that derive their nutrients directly from the water through the cell wall or by means of a well-developed root system are also in this group. Water is critical for support of the plant or its leaves.



A Duckweed and Watermeal infestation



TREATMENT TIPS

This family of plants is notorious for their rapid reproduction. Effective control is dependent upon chemical contact with as many of the plants as possible. This includes those washed up along shorelines or trapped in backwater areas. Several treatments may be necessary to achieve control. Plants shown in the above drawings can be roughly compared to the size of a penny.

DUCKWEED (Lemnaceae) family
Small, floating green plants that are often mistaken for algae. Reproduction is by means of fragmentation. Common in quiet water such as ponds or backwaters.

COMMON DUCKWEED *(Lemna minor)* - Figure A
Description: Plants are oval and roots may or may not extend from the underside.

WATERMEAL *(Wolffia spp.)* - Figure B
Description: This smallest of flowering plants, granular in size, is usually abundant when present and displays no roots. Plants are often mistaken for seeds. Extremely difficult to control.

STAR DUCKWEED *(Lemna trisulca)* - Figure C
Description: Plants are long and narrow with stalked appendages and rootlets.

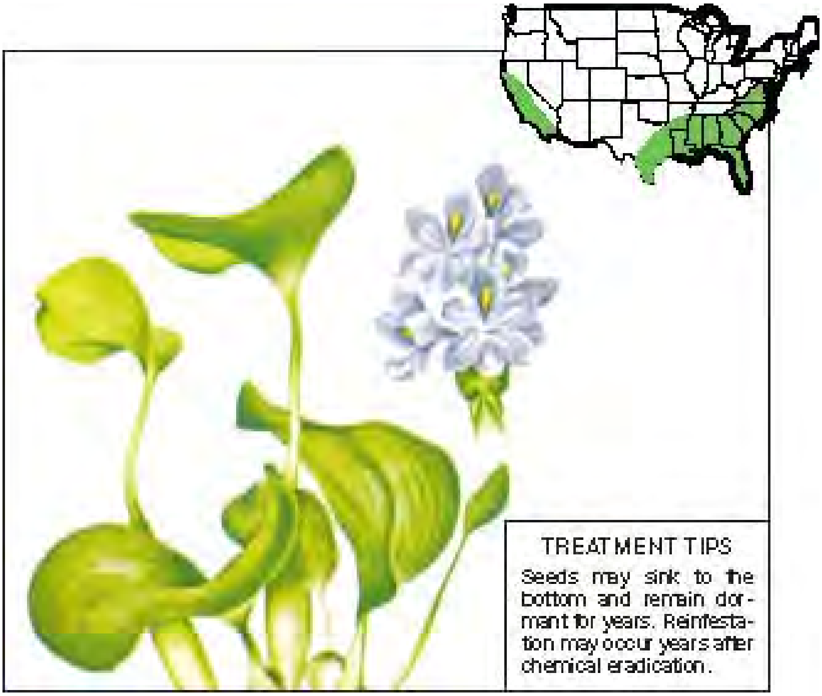
Distribution: All three found throughout the United States.

Recommended Control Method: All members of the duckweed family can be controlled with the following combination:
For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 10 parts **Weedtrine®-D.** Add non-ionic surfactant and apply at the rate of 1 gallon per 1/5 surface acre.*

OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 2 parts Reward. Add non-ionic surfactant and apply at the rate of 1.5 gallons per surface acre. *
*Dilute to facilitate even distribution as a fine surface spray.

Alternate Control Methods:
Fluridone (various liquid or pelletized formulations): see label.



WATER HYACINTH *(Eichhornia crassipes)*

Description: Plants are free-floating or rooted in mud. Leaves are large and broadly lance-like extending from an inflated stalk. Flowers are blue, violet or white. Roots are dark and fibrous. Leaf blades may be up to 8 inches (20 cm) long and 2 to 6 inches (5 to15 cm) wide. Plant height is variable from a few inches up to 3 feet tall. Plants reproduce by fragmentation or by seeds.

Distribution: Common in tropical and subtropical areas of the United States (Florida, Texas and gulf coast region).

Recommended Control Method: For areas where chemical drift is a critical concern, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 1 gallon per surface acre of foliage. Dilute to facilitate even distribution. Use non-ionic surfactant.

Alternative Control Method:
Shore-Klear™: 1-1/3 (1.3) ounces per gallon of water plus non-ionic surfactant. 75 gallons of solution will treat 1 acre.

TREATMENT TIPS

Dense growths of these plants may be beneficial in deeper canals. They help shade out underlying submerged weeds that often interfere with navigation and impede water flow. Chemical should be sprayed directly onto foliage.

COMMON SALVINIA *(Salvinia rotundifolia)*

Description: A small floating fern with "leaves" (fronds) arranged along a common stem. The bright green leaf is less than 1/2 inch (12 mm) long, has a distinct mid-rib and often appears folded along its axis. **

Distribution: Introduced from Mexico or South America. The plant is commonly found in Florida in association with alligator weed and water hyacinth.

Recommended Control Method: For areas less than 1 acre, apply tank mix 1 part **Cutrine-Plus** to 10 parts **Weedtrine-D**. Apply at the rate of 70 to 95 ounces per 1/5 acre. *

OR

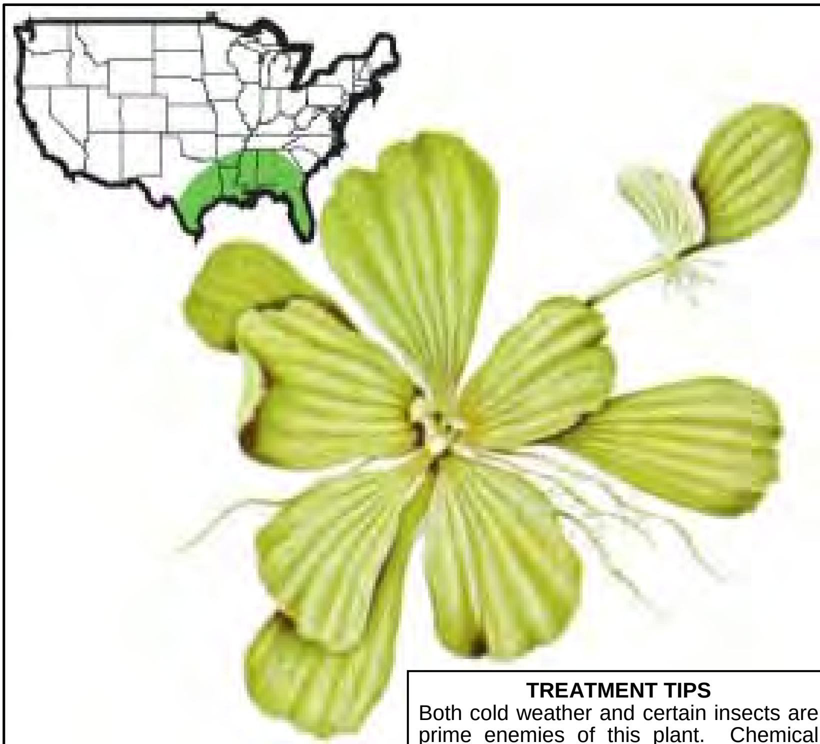
For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 2 parts Reward. Apply at the rate of 3/4-1 gallon per surface acre. *

*Dilute to facilitate even distribution. Add non-ionic surfactant. Spray to saturate foliage.

Alternative Control Method:

Reward: 1/2 to 3/4 gallon per surface acre.

** Axis: the stem, the longitudinal support on which organs are arranged.



TREATMENT TIPS
Both cold weather and certain insects are prime enemies of this plant. Chemical methods are best used in areas where year-round control is desired.

WATER LETTUCE *(Pistia stratioties)*

Description: Plants consist of distinct rosettes** of light yellow-green leaves approximately 4 to 8 inches (10-20 cm) long. Tufts of long un-branched, fibrous roots extend into the water from fleshy rhizome. Leaves have definite veins radiating from leaf base toward leaf margin.

Distribution: Commonly found in quiet water areas in Florida as well as isolated areas in other Gulf Coast states.

Recommended Control Method: For areas less than 1/2 acre, tank mix 1 part **Cutrine-Plus** to 10 parts **Weedtrine-D.** Apply at the rate of 70 to 95 ounces per 1/5 acre. *

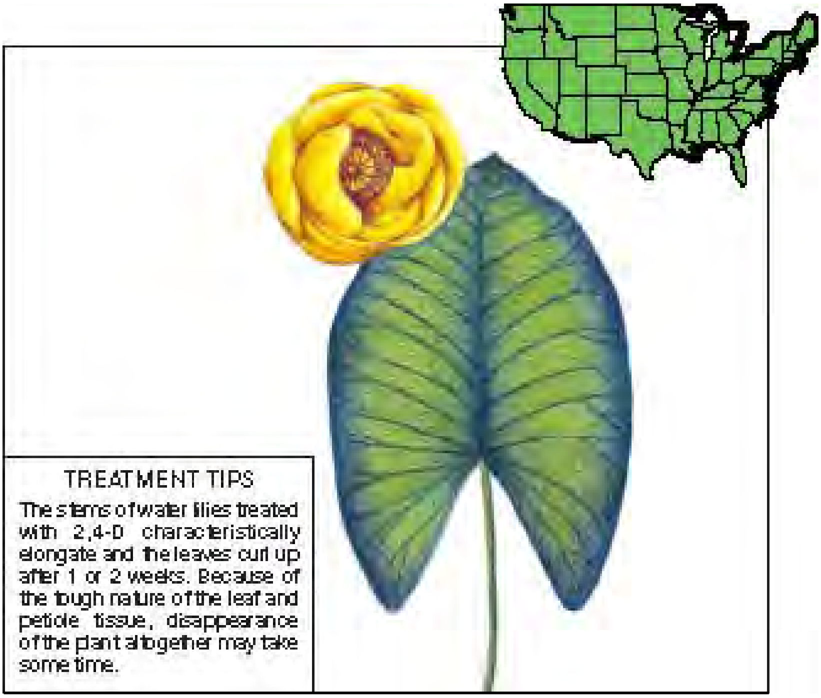
OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 2 parts Reward. Apply at the rate of 3/4 to 1 gallon per surface acre. *

*Dilute to facilitate even distribution. Add non-ionic surfactant. Spray to saturate foliage.

Alternative Control Methods:
Reward: 1/2 to 3/4 gallon per surface acre.

**Rosette: a dense basal cluster of leaves arranged in circular fashion like the leaves of the common dandelion.



TREATMENT TIPS

The stems of water lilies treated with 2,4-D characteristically elongate and the leaves curl up after 1 or 2 weeks. Because of the tough nature of the leaf and petiole tissue, disappearance of the plant altogether may take some time.

YELLOW WATER LILY *(Nuphar spp.)* - **Common names:** Spatterdock, Yellow Cow Lily

Description: Leaves large, heart-shaped, commonly 8 to 16 inches (20 to 40 cm) long. Leaf veins extend laterally from the midrib. Flower is bright yellow, with a single row of petals. Spreads horizontally from rhizome similar to White Water Lily (see page 42).

Distribution: Prefer muck or silt bottom in stagnant, shallow areas.

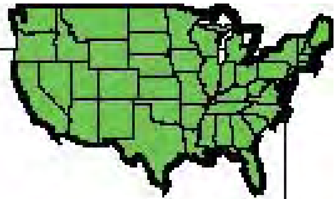
> **Recommended Control Method:** Apply 150 to 200 lbs. of **Navigate** per surface acre. Distribute granules evenly to assure effective control.

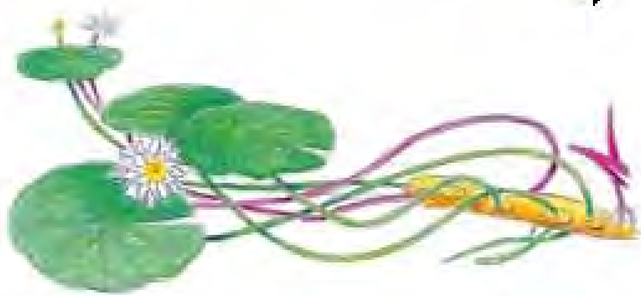
Alternative Control Methods:

- 2,4-D Liquid ester: (see label).
- **Shore-Klear**: 3/4 gallon per surface acre (plus non-ionic surfactant).
- Fluridone: (various liquid or pelletized formulations): see label.

Note: Navigate and 2,4-D treatments are only effective early in the season on new growth. Shore-Klear should be used where plants have already reached flowering stage.

TREATMENT TIPS
The White Water Lily is sometimes intentionally planted for aesthetics or as a fish habitat. It can be quite prolific and create a problem in some areas.





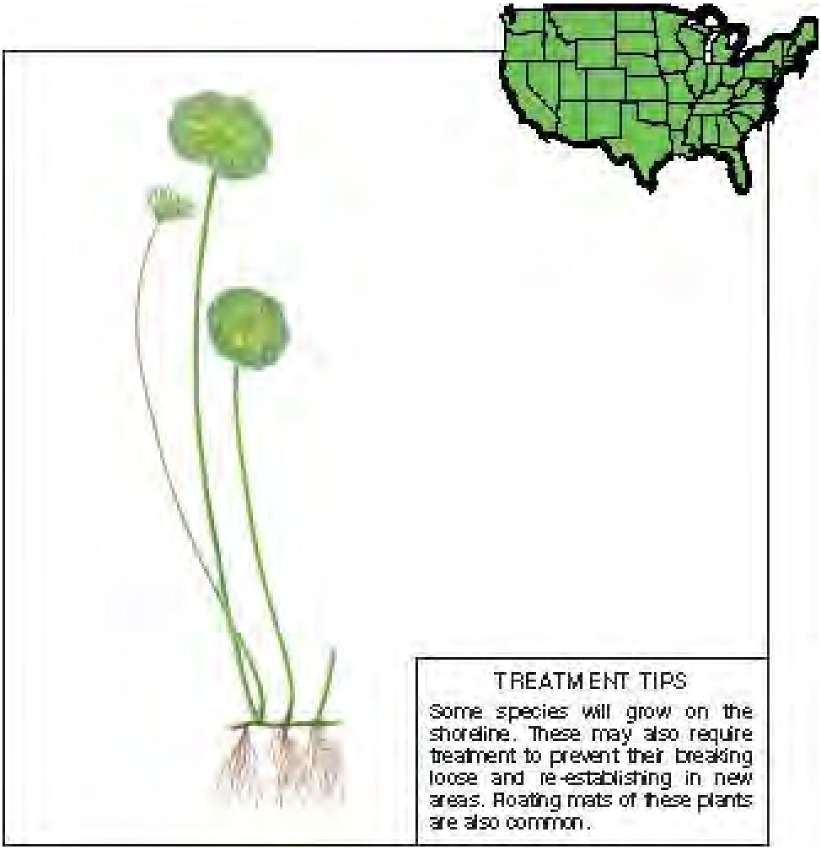
WHITE WATER LILY *(Nymphaea spp.)-* **Common name:** Fragrant Water Lily

Description: Large, round, cleft* leaf 6 to 12 inches (15 to 30 cm) in diameter. Leaf veins radiate from point of attachment to petiole. ** The underside of the leaf is purplish-red and the flower is white with multiple rows of petals. Plant has a thick, fleshy rhizome network buried in the mud.

Distribution: Common in shallow water throughout the United States. Prefers a muck or silt bottom. Able to withstand a wide variance in pH.

See page 41 for **Control Methods**.

*Cleft: cut about halfway to the mid-vein. **Petiole: the stalk of a leaf blade.



WATER PENNYWORT *(Hydrocotyle spp.)*

Description: Mature leaves round with broad lobes. Leaves about the size of a half dollar. Stalks extend from a horizontal root buried in shallow water and are attached centrally to the leaf.

Distribution: Common throughout the United States, but seldom reaching nuisance levels.

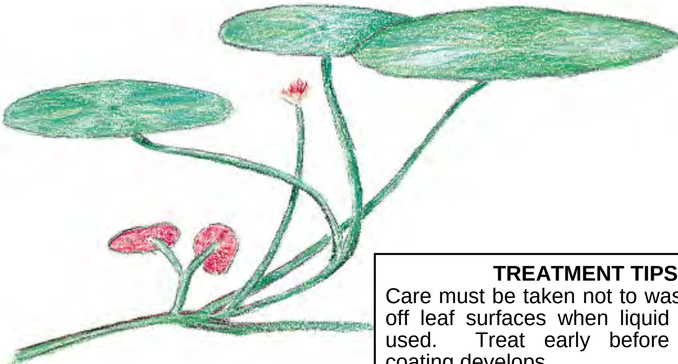
Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 10 parts **Weedtrine-D** and apply at the rate of 70 to 95 ounces per 1/5 acre. *

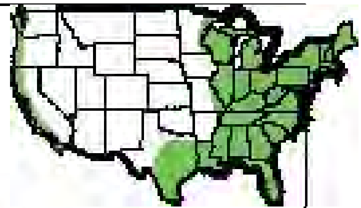
OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 2 parts Reward and apply at the rate of 3/4 gallon per surface acre. *

* Dilute to facilitate even distribution. Add non-ionic surfactant. Spray to saturate foliage.

Alternative Control Methods:
Reward: 3/4 gallon per surface acre plus non-ionic surfactant.





TREATMENT TIPS

Care must be taken not to wash chemical off leaf surfaces when liquid sprays are used. Treat early before gelatinous coating develops.

WATERSHIELD *(Brasenia schreberi)* - **Common name:** Dollar bonnet

Description: Floating leaves that are oval to elliptical with smooth, un-lobed edges. The "stem" (petiole) is attached to the middle of the leaf. Leaves may be 2 to 5 inches (5 to 10 cm) in length. A slimy, gelatinous coating covers the underside of the leaf and stem particularly on mature plants. A dull, purple flower is produced in early summer. Growth is from a rootstock.

Distribution: Usually found in shallow, acid waters throughout the eastern United States, Gulf regions and Pacific coast.

Recommended Control Method: Apply 150 to 200 pounds of **Navigate** per surface acre. Distribute granules evenly to assure effective control.

Alternative Control Methods:

- 2,4-D Liquid ester: (see label).
- Shore-Klear: 3/4 gallon per surface acre (plus non-ionic surfactant).

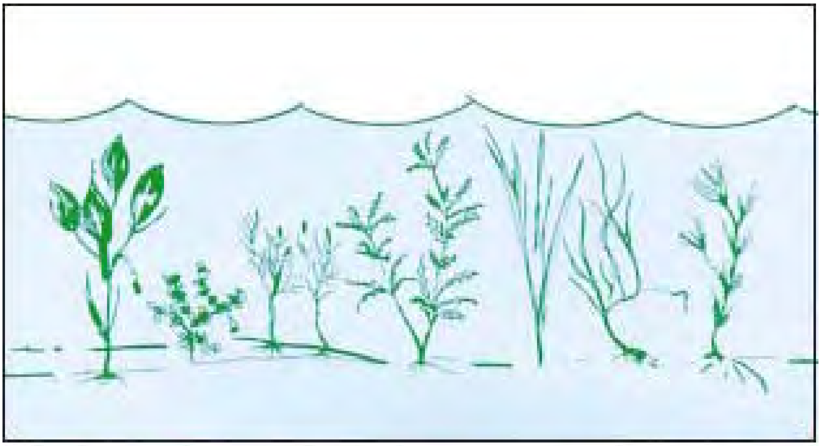
ATTENTION: RECOMMENDATION FACTORS

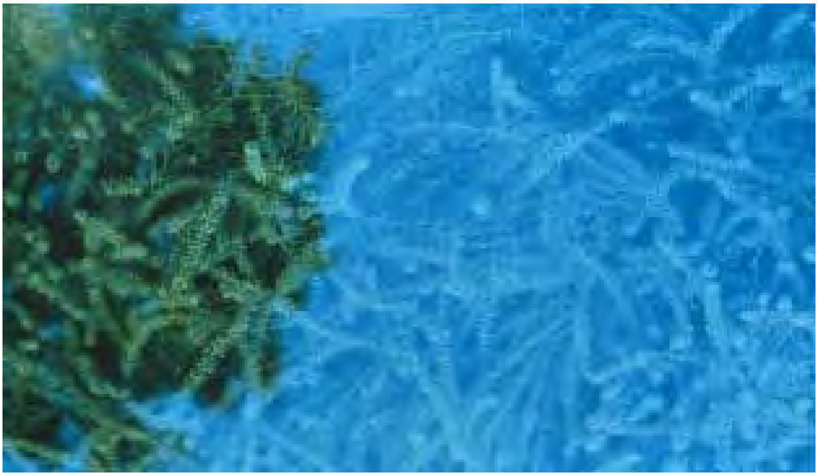
Many factors have been considered in our recommendations such as effectiveness, toxicity, environmental impact, ease of application and economics. Alternative control methods may be necessary due to water use restrictions (see page 110). Plant distribution within the U.S. is shown on shaded maps accompanying weed pictures. Most of these plants, or closely related species, are found worldwide. Trade names mentioned in this book have manufacturer references in Appendix A, pages 107-109. Alternative Control Methods are listed alphabetically - not in order of preference.

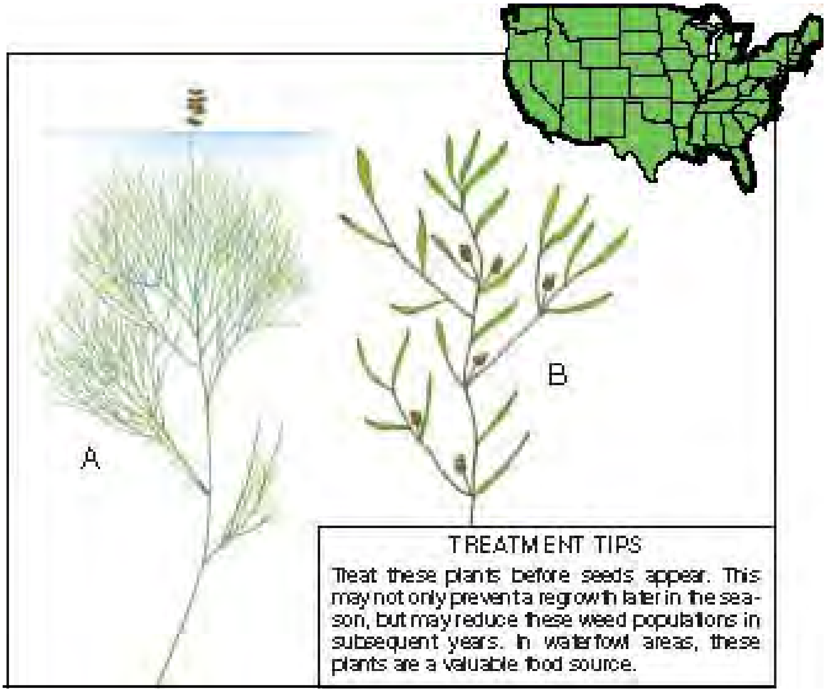
SUBMERGED WEEDS

Plants that are generally rooted at the bottom and are completely underwater are in this category. Submerged weeds are usually flaccid* and lack rigid cellular tissue. Flowers, if present, may extend above the water surface.

* Flaccid: lax and weak, without rigidity.







SAGO PONDWEED *(Potamogeton pectinatus)* - Figure A

Description: Plants are bushy in appearance with narrow thread-like leaves alternately arranged on the stem. Nutlets* are arranged like beads spaced on a string and emerge from the water.

LEAFY-PONDWEED *(Potamogeton foliosus)* - Figure B

Description: Short, grass-like submersed leaves. Clumps of 4 to 8 fruiting bodies are attached to a center stem by a short seed stalk. Grows from shallow water to a depth of 4 feet.

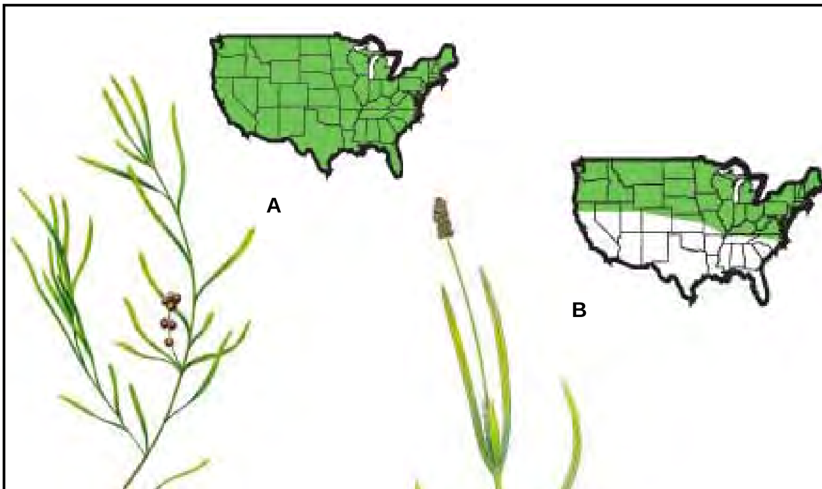
Distribution: Occur throughout the United States in highly variable forms based on local conditions.

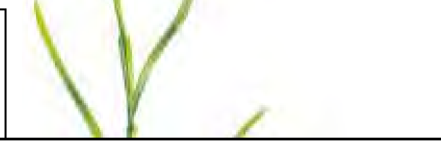
Recommended Control Method: Tank mix 1 part **Cutrine-Plus** to 2 parts Aquathol® K. Apply at the rate of 1 gallon per acre-foot of water. Dilute to facilitate even distribution.
Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

Aquathol® Granular: 27 to 81 pounds per acre-foot.
Aquathol K liquid: 0.6 to 1.9 gallons per acre-foot.
Clearigate: 4.4 to 8.7 gallons per acre-foot.
Cutrine-Plus/Reward: Tank mix in the ratio of 1:1. Apply 2 gallons per surface acre.
Reward: 2 gallons per surface acre.
Fluridone: (various liquid or pelletized formulations): see label.

* Nutlets: a small nut or nut-like fruit.





TREATMENT TIPS

Where these plants grow in relatively deep water (6-8 feet), they can be treated more economically with granular herbicides.

SMALL PONDWEED *(Potamogeton pusillus)* - Figure A

Description: Plant with numerous lateral branches on a slender stem. Narrow ribbon-like leaves are alternately arranged on branches. Leaves tapered to point of attachment on stem. Nutlets arranged on spike in a loose pattern.

Distribution: Found throughout the United States. A common nuisance species in ponds, lakes and irrigation ditches.

FLAT-STEMMED PONDWEED *(Potamogeton zosteriformis)* - Figure B

Description: Stem large and conspicuously flattened. Leaves ribbon-like and extended upwards from flattened surface of stem.

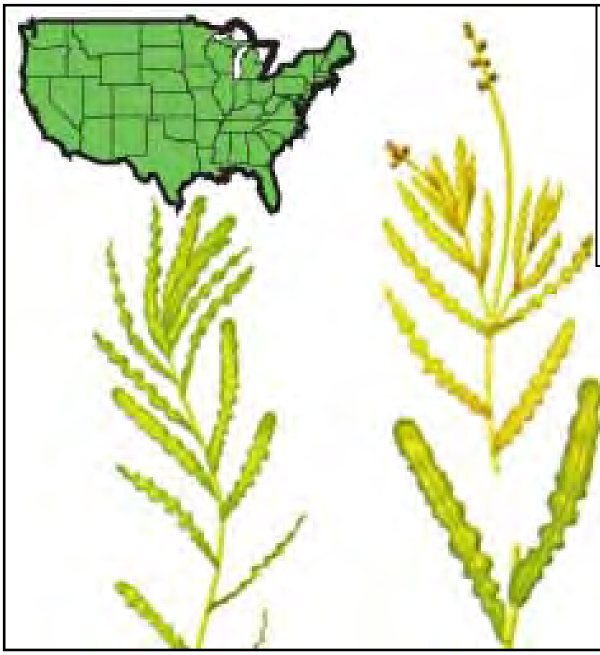
Distribution: Common throughout northern one-half of U.S. Plants seldom reach nuisance levels.

Recommended Control Method: Tank mix 1 part **Cutrine-Plus** to 2 parts Aquathol K. Apply at the rate of 1 gallon per acre-foot of water. Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

- Aquathol Granular: 27 to 81 pounds per acre-foot.
- Aquathol K liquid: 0.6 to 1.9 gallons per acre-foot.
- **Cutrine-Plus**/Reward: Tank mix in the ratio of 1:1. Apply 2 gallons per surface acre.
- Fluridone: (various liquid or pelletized formulations): see label.



TREATMENT TIPS
This plant tends to grow profusely early in the season, often shading and inhibiting other weed growth. Re-growth of this weed rarely occurs in the same season after control has been achieved.

CURLY-LEAF PONDWEED *(Potamogeton crispus)*

Description: Leaves are thin and membranous with veins plainly visible. Minute teeth visible along entire margin of leaf. Commonly grows early in the spring and dies back during midsummer. Fruits borne in spike above the water surface. Leaves alternately arranged on stem.

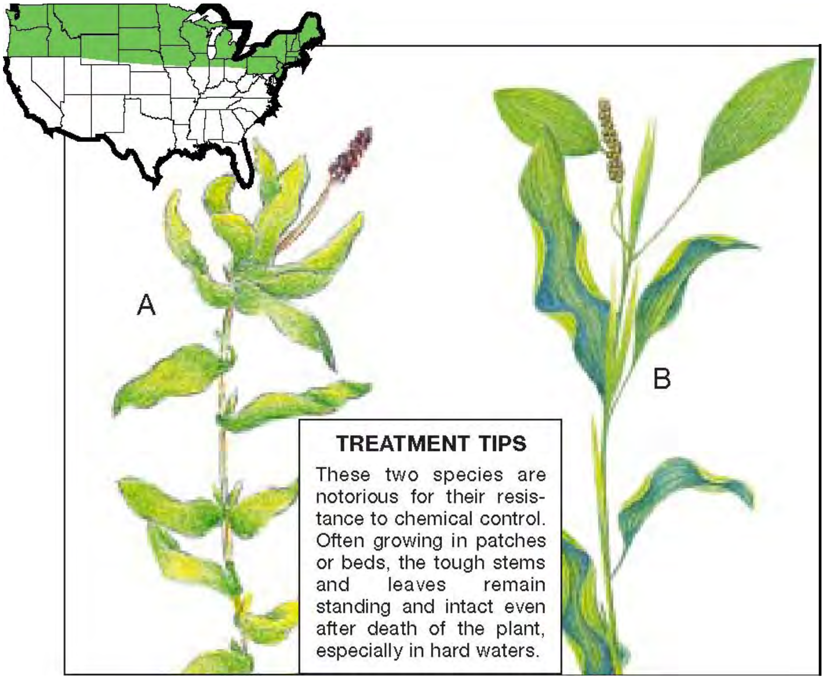
Distribution: Common throughout the U.S. in fresh and brackish water.

Recommended Control Method: Tank mix 1 part **Cutrine-Plus** to 2 parts Aquathol K. Apply at the rate of 1 gallon per acre-foot of water. Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

- Aquathol Granular: 13 to 81 pounds per acre-foot.
- Aquathol K liquid: 0.3 to 1.9 gallons per acre-foot.
- **Cutrine-Plus**/Reward: Tank mix in the ratio of 1:1. Apply 2 gallons per surface acre.
- Reward: 2 gallons per surface acre.
- Fluridone: (various liquid or pelletized formulations): see label.



CLASPING-LEAF PONDWEED *(Potamogeton richardsonii)* - Figure A

Description: Leaves are wide and wavy with a broad base which appears to extend three-quarters of the way around the stem. Upper stem commonly branched and leafy. Leaves alternately arranged on stem.

LARGE-LEAF PONDWEED *(Potamogeton amplifolius)* - Figure B

Description: Large, thick stem with wavy, re-curved, oblong, submersed leaves which taper to the stem. Floating leaves are ovate*. Solid, tightly packed spike of nutlets at tip of the plant. Plant is seldom branched.

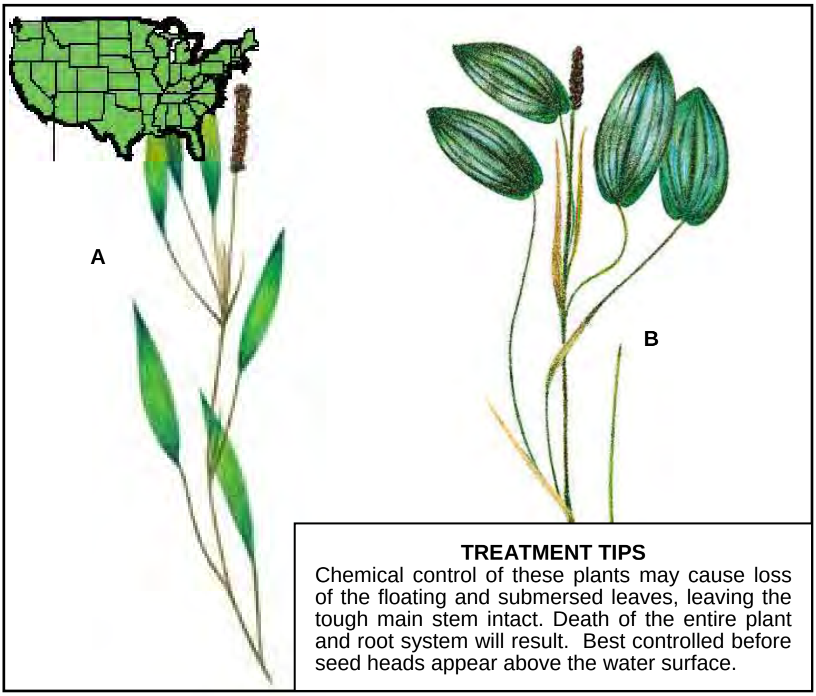
Distribution: Common in hard water throughout the northern half of U.S. Plants often appear brown due to mineral deposits on leaves.

Recommended Control Method: Tank mix 1 part **Cutrine-Plus** to 2 parts Aquathol K. Apply at the rate of 2 gallon per acre-foot of water. Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:
- Aquathol Granular: 54 to 108 pounds per acre-foot.
- Aquathol K liquid: 1.3 to 2.6 gallons per acre-foot.
- Reward: 2 gallons per surface acre (conditional control).
- Fluridone: (various liquid or pelletized formulations): see label.

* Ovate: shaped like an egg with the broader end downward.



TREATMENT TIPS

Chemical control of these plants may cause loss of the floating and submersed leaves, leaving the tough main stem intact. Death of the entire plant and root system will result. Best controlled before seed heads appear above the water surface.

AMERICAN PONDWEED *(Potamogeton americanus)* - Figure A

Description: Floating leaves are oval with base tapered to distinct petiole. Submersed leaves are oval to lance-like, tapered to long petiole. Generally plant has sparse leafing. Leaves alternately arranged on stem.

FLOATING-LEAF PONDWEED *(Potamogeton natans)* - Figure B

Description: Floating leaves are slightly heart-shaped at base. Submersed leaves are long and narrow or absent.

Similar Species:

ILLINOIS PONDWEED *(Potamogeton illinoensis)* - Not Pictured

Description: Similar to above species. Submersed leaves differ from above in that petiole is extremely short.

Distribution: Widespread and common throughout U.S.

Recommended Control Method: Tank mix 1 part **Cutrine-Plus** to 2 parts Aquathol K. Apply at the rate of 2 gallons per acre-foot of water. Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

- Aquathol Granular: 54 to 108 pounds per acre-foot.
- Aquathol K liquid: 1.3 to 2.6 gallons per acre-foot.
- Reward: 2 gallons per surface acre (conditional control).
- Fluridone: (various liquid or pelletized formulations): see label.

TREATMENT TIPS

Although this weed rarely interferes with swimming and boat-ing, it is commonly found on the ends of fish lines. It is usually controlled with a single treatment.

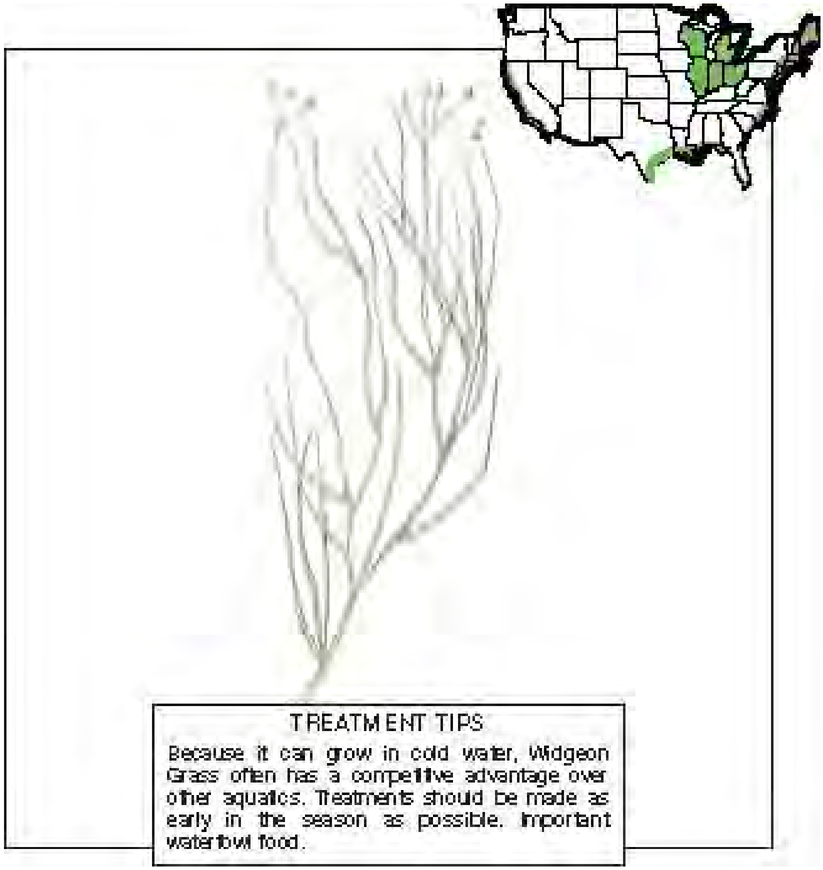
HORNED PONDWEED *(Zannechellia palustris)*
Description: Unlike the true pondweeds, this species has all leaves oppositely arranged on the stem. The fragile stem rises from a horizontal root. Leaves are long and narrow with flattish seeds attached to the stem at the base of the leaves.

Distribution: Species and its varieties found throughout the U.S. in fresh or brackish water. Not a common nuisance species.

Recommended Control Method: Tank mix 1 part **Cutrine-Plus** to 2 parts Aquathol K. Apply at the rate of 1 gallon per acre-foot of water. Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:
- Aquathol Granular: 54 to 81 pounds per acre-foot.
- Aquathol K liquid: 1.2 to 1.9 gallons per acre-foot.



WIDGEON GRASS *(Ruppia maritima)*

Description: Leaves are thread-like and narrow, extending from an extensive buried root system. Four to six fruits borne in clusters on short stalks at the top of the plants.

Distribution: Commonly found in shallow, brackish water or alkaline waters. Mainly along coastal areas, but scattered into many inland midwestern lakes. Plant is a prime waterfowl food and desirable in some conditions.

Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 5 parts **Weedtrine-D**. Apply at the rate of 1.2 gallons per 1/5 surface acre. *

OR

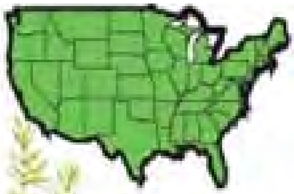
For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 2 gallons per surface acre. *

*Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Method:

Reward: 1.5 gallons per surface acre.



TREATMENT TIPS

Plants often grow in thick clumps or beds. Good coverage and dispersion of chemical is required to achieve control. Inject chemical if growth is in deep water.

SOUTHERN NAIAD *(Najas guadalupensis)*

Description: Plant is very leafy. Leaves are wider at the base and arranged oppositely or in whorls of three on the plant stem. A tiny seed is concealed in the axis of leaf. Leaf margin with visible spines.

Similar Species:

COMMON NAIAD *(Najas flexilis)*

Description: Leaves tapered to fine point with minute spines on margin.

Distribution: Both species are common and widespread with considerable overlap in range.

Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 5 parts **Weedtrine-D**. Apply at the rate of 0.9 gallon per 1/5 surface acre. *

OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 1.5 gallons per surface acre. *

* Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

- Aquathol K liquid: 1.0 to 1.9 gallons per acre-foot.
- Reward: 1 to 2 gallons per surface acre.
- Fluridone: (various liquid or pelletized formulations): see label.

TREATMENT TIPS
Avoid fragmenting plants as they break very easily. Disintegrate readily after they die.

BRITTLE NAIAD *(Najas minor)*

Description: Long, pointed leaves with distinct spines. Leaves oppositely arranged on stem. Entire plant is brittle and breaks easily.

Distribution: Found throughout the U.S. sometimes reaching nuisance concentration.

Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 5 parts **Weedtrine-D**. Apply at the rate of 0.9 gallon per 1/5 surface acre. *

OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 1.5 gallons per surface acre. *

* Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:
- Aquathol K liquid: 1.0 to 1.9 gallons per acre-foot.
- Reward: 1 to 2 gallons per surface acre.
- Fluridone: (various liquid or pelletized formulations): see label.

TREATMENT TIPS

When treating these plants with Reward in shallow muddy areas, be careful not to stir up the bottom sediments that will neutralize the chemical.

WATERSTARGRASS *(Heteranthera dubia)*

Description: Stems and leaves are long, flexible and grass-like. Found submersed in shallow water. Leaves are flaccid with no visible mid-rib. The flower is small, yellow and star-shaped.

Distribution: Found throughout the U.S., generally in still water.

Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 5 parts **Weedtrine-D**. Apply at the rate of ¾ to 1½ gallons per 1/5 acre.*

OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 1 to 2 gallons per surface acre. *

OR

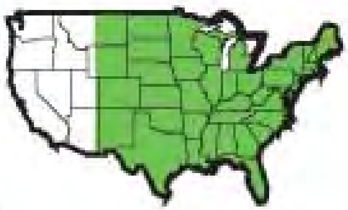
Tank mix 1 part Cutrine-Plus to 2 parts Aquathol K. Apply at the rate of 2 gallons per acre-foot.

*Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

- Navigate: 100 pounds per surface acre.
- Aquathol Granular: 54 to 108 pounds per acre-foot.
- Aquathol K liquid: 1.3 to 2.6 gallons per acre-foot.
- Reward: 1 to 2 gallons per surface acre.



TREATMENT TIPS
Very difficult to control. Floating, uprooted plants often re-establish themselves in shallow waters. Take note of "**Fish Caution"** on Hydrothol 191 labels.

WILD CELERY, TAPEGRASS, EELGRASS *(Vallisneria americana)*

Description: Roots buried in mud with tufts of ribbon-like, flaccid leaves. Plant has horizontal stem system connecting tufts of leaves. Flower visible late in summer supported by a coiled stalk.

Distribution: Commonly found in fresh water from the Great Plains east to the coast.

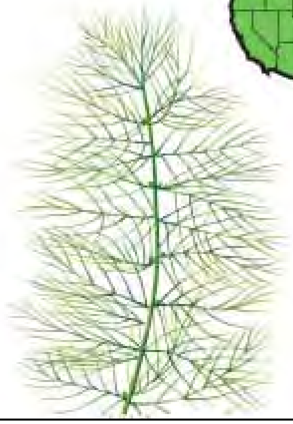
Often occurs in extensive patches crowding out all other growth. Granular herbicide is most effective on low growing plants. Treat when plants are established, before flowering occurs.

Recommended Control Method: Apply Hydrothol® 191 Granular evenly over the water surface at the rate of 27 to 136 pounds per acre-foot.

OR

Apply Hydrothol 191 Liquid at the rate of 1 to 3 gallons per acre-foot. Suggested for use by commercial applicators only.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.



TREATMENT TIPS

Often occurs in extensive patches crowding out all other growth. Granular herbicide is most effective on low growing plants. Treat when plants are established, before flowering occurs.

WATERMILFOIL *(Myriophyllum spp.)* - Figure A

Description: Stem is hollow with whorled leaves at intervals along entire length of plant. Leaves are finely dissected to mid-rib and feather-like in appearance. Plant submerged except for a stalk of tiny flowers which may extend above water surface. Do not confuse with Chara (see page 34).

PARROT FEATHER *(Myriophyllum brasiliense)* - Figure B

Description: An escaped South American species; has stem and feather-like leaves extending above water surface. Do not confuse with Chara (see page 34).

Distribution: Numerous species of milfoil are common throughout the U.S.

Recommended Control Method: Apply **Navigate** evenly at the rate of 100 pounds per surface acre. Use for early season application on low-growing plants.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

Aquathol Granular: 81 to 108 pounds per acre-foot.

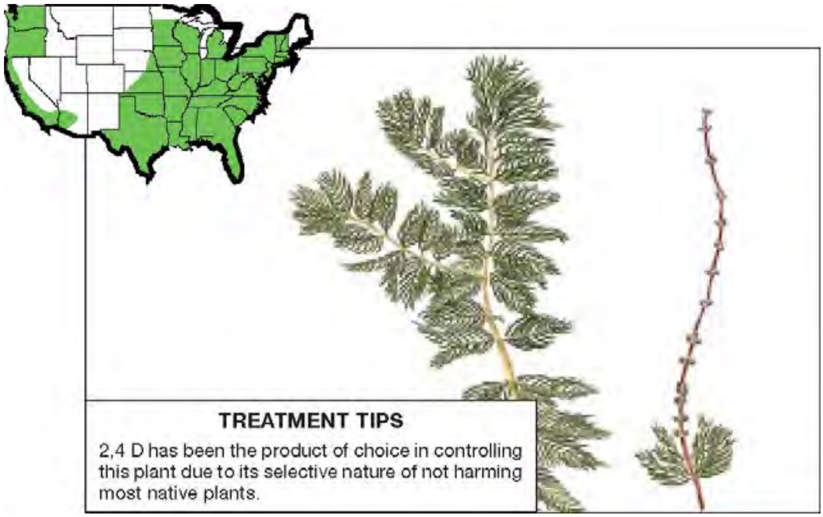
Aquathol K liquid: 1.9 to 2.6 gallons per acre-foot.

Cutrine-Plus/Aquathol K: tank mix at the ratio of 1:3. Apply at the rate of 2 gallons per acre-foot.

Cutrine-Plus/Reward: tank mix at the ratio of 1:1. Apply at the rate of 1 to 2 gallons per surface acre.

Reward: 1 to 2 gallons per surface acre.

Fluridone: (various liquid or pelletized formulations): see label.



EURASIAN WATERMILFOIL *(Myriophyllum spicatum)*

Description: Leaves in whorls of 4 with 14 to 20 pairs of leaf divisions. Stalk of tiny, reddish flowers may extend above or on the water surface. Plant may reach lengths of 10 ft. *(3 m)* or more. Plant stems and leaves may become calcified in hard water areas.

NOTE: This species is an exotic plant, introduced to the U.S. by the aquarium industry, and it is rapidly becoming a major nuisance throughout North America. It is capable of rapid dispersion, principally by fragmentation of plant parts. Each fragment is capable of growing roots and developing into a new plant. Removal of fragments from boat trailers and along shorelines is advised to prevent its spread into new areas. Eurasian Watermilfoil is quite competitive with native species and may completely dominate a plant community within a few years after introduction. Due to the plant's ability to form dense growth, water use activities may become severely impaired. These plants are of little value to wildlife or fisheries.

Recommended Control Method: Apply **Navigate** evenly at the rate of 100 pounds per surface acre. Use for early season application on low-growing plants.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

- Aquathol Granular: 81 to 108 pounds per acre-foot.
- Aquathol K liquid: 1.9 to 2.6 gallons per acre-foot.
- **Cutrine-Plus**/Aquathol K: tank mix at the ratio of 1:3. Apply at the rate of 2 gallons per acre-foot.
- **Cutrine-Plus**/Reward: tank mix at the ratio of 1:1. Apply at the rate of 1-2 gallons per surface acre.
- Reward: 1 to 2 gallons per surface acre.
- Fluridone: (various liquid or pelletized formulations): see label.

COONTAIL *(Ceratophyllum demersum)*

Description: Plants are submersed and without roots. Leaves are dark green in color and arranged in whorls on the stem. Coontail can be distinguished from milfoil by the forking of the leaves rather than the feather-like divisions. Spacing between leaf whorls is highly variable. Consequently, plants may be bushy or extremely long and sparse.

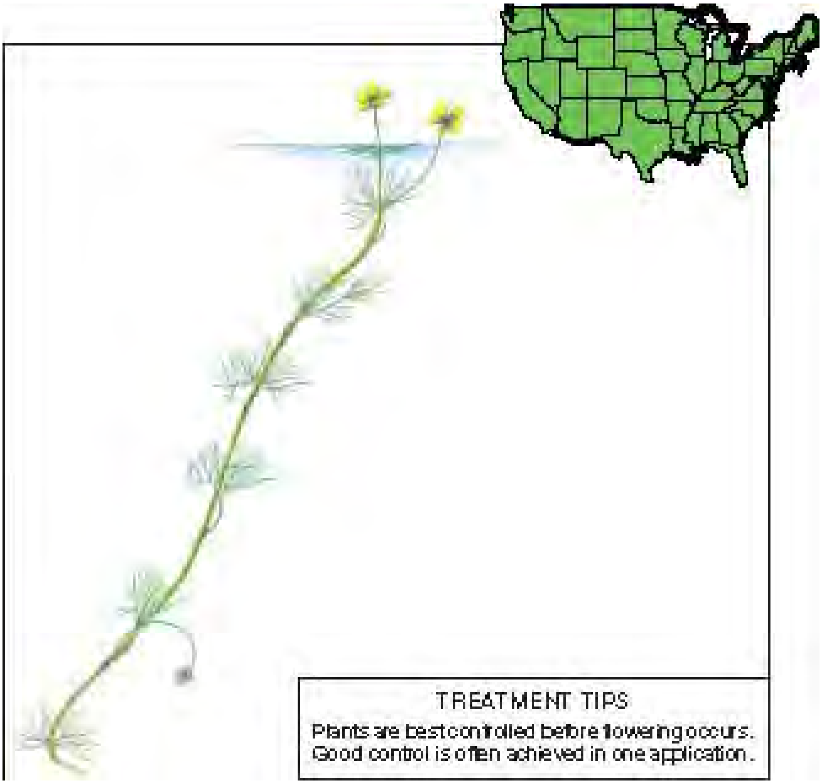
Distribution: Found throughout the U.S., usually in hard water.

Recommended Control Method: Apply **Navigate** evenly at the rate of 150 to 200 pounds per acre. Use for early season applications on low-growing plants.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

- Aquathol Granular: 54 to 81 pounds per acre-foot.
- Aquathol K liquid: 1.3 to 1.9 gallons per acre-foot.
- **Cutrine-Plus**/Aquathol K: tank mix at the ratio of 1:3. Apply at the rate of 2 gallons per acre-foot.
- **Cutrine-Plus**/Reward: tank mix at the ratio of 1:1. Apply at the rate of 1 to 2 gallons per surface acre.
- Reward: 2 gallons per surface acre.
- Fluridone: (various liquid or pelletized formulations): see label.



WATER BUTTERCUP *(Ranunculus spp.)*

Description: Submersed stem is erect in water. Tufts of thread-like leaves alternate along the stem. Conspicuous yellow or white flowers emerge from the water from June through September. Do not confuse with Chara (see page 34).

Distribution: Various species common throughout the United States.

Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 5 parts **Weedtrine-D**. Apply at the rate of 1½ gallons per 1/5 surface acre. *****

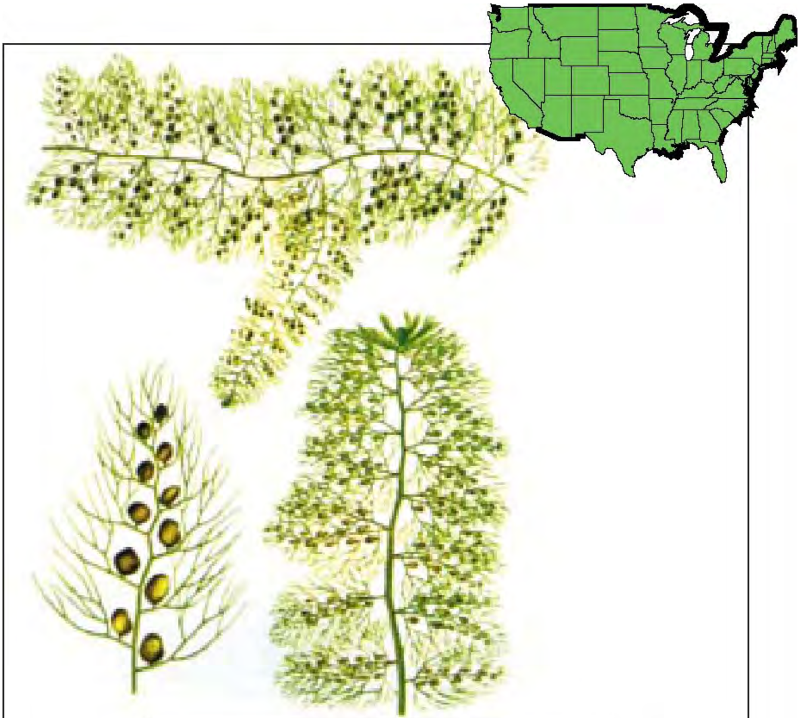
OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 2 gallons per surface acre. *****

*****Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Method:
Reward: 1 to 2 gallons per surface acre.



TREATMENT TIPS

This plant is not rooted and floating plants may re-infest treated areas.

BLADDERWORT *(Utricularia spp.)*

Description: Plants are free-floating and without visible roots. Finely divided leaves are scattered along the stem with numerous small bladder-like structures on the leaves. These bladders act as traps to capture small aquatic invertebrates.

Distribution: Genus common throughout the United States.

Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 5 parts **Weedtrine-D**. Apply at the rate of 1½ gallons per 1/5 surface acre. *****

OR

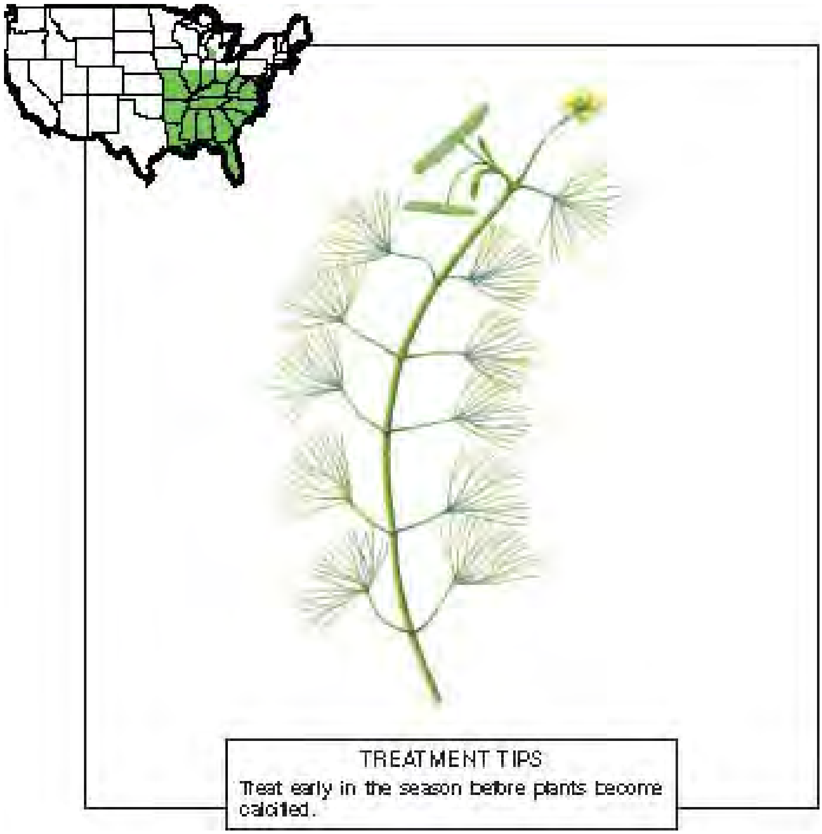
For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 2 gallons per surface acre. *****

*****Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

- **Navigate**: 150 to 200 pounds per surface acre.
- Reward: 1 to 2 gallons per surface acre.
- Fluridone: (various liquid or pelletized formulations): see label.



CABOMBA *(Cabomba caroliniana)* - **Common name:** Fanwort
Description: Submersed leaves are oppositely arranged on the stem. The leaves are fan-shaped and dissected into many narrow segments. Un-dissected floating leaves may also be present. Flower is white to light yellow and emerges from the water. Do not confuse with Chara (see page 34).

Distribution: Southeastern quarter of the United States, north to central Illinois.

Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 5 parts **Weedtrine-D**. Apply at the rate of 1½ gallons per 1/5 surface acre. *****

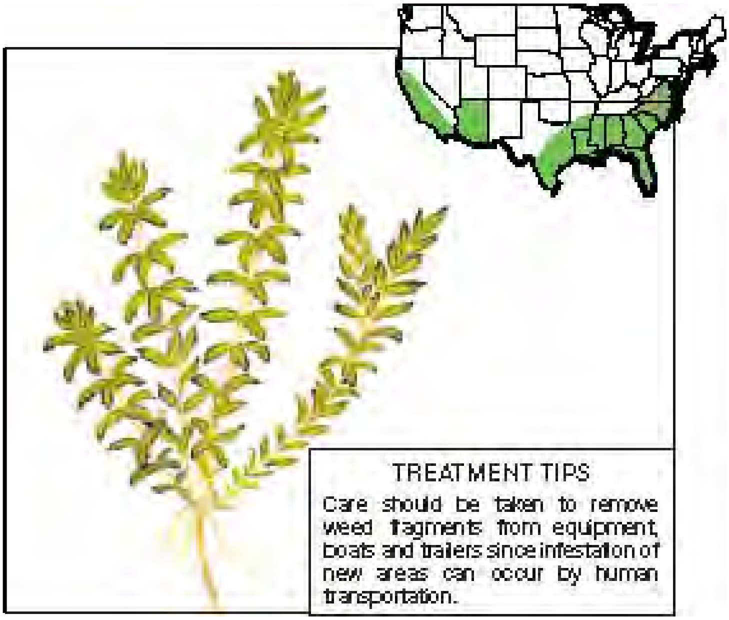
OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 2 gallons per surface acre. *****

*****Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:
Reward: 1 to 2 gallons per surface acre.



HYDRILLA *(Hydrilla verticillata)* - **Common name:** Florida Elodea

Description: Stem is long and branched with oppositely arranged leaves at the bottom and whorls of 3 leaves on the upper portion of the plant. Leaf is oval- shaped with margins toothed. There are pointed spines on the mid-rib of the underside of the leaf. Plant fragments are capable of reproduction.

Similar Species:

BRAZILIAN ELODEA *(Egeria densa)* - Not pictured

Description: Plants are very similar to Hydrilla but the leaves are not toothed. A visual inspection and handling of the leaves will quickly distinguish it from Hydrilla. Both species are controlled with similar treatment.

Distribution: California, Arizona, Gulf states and southeastern states north to Washington, D.C.

Recommended Control Method: Tank mix 3⅓ gallons of **Cutrine-Plus** with 2 gallons of Reward and inject below the surface. For soft water, reduce **Cutrine-Plus** to 2 gallons. Above recommendations will treat 1 acre.

OR

Apply **Clearigate** at the rate of 3.6 to 8.7 gallons per acre-foot for Hydrilla or 5.4 to 8.7 gallons per acre-foot for Brazilian Elodea.

OR

Apply **Cutrine-Plus** at the rate of 1.2 to 3.0 gallons per acre-foot in areas where water use restrictions are prohibitive.

OR

Tank mix 5 parts Aquathol K to 3 parts **Cutrine-Plus** and apply at the rate of 2 gallons per acre-foot.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart (2 quarts for Hydrilla) per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

Fluridone: (various liquid or pelletized formulations): see label.

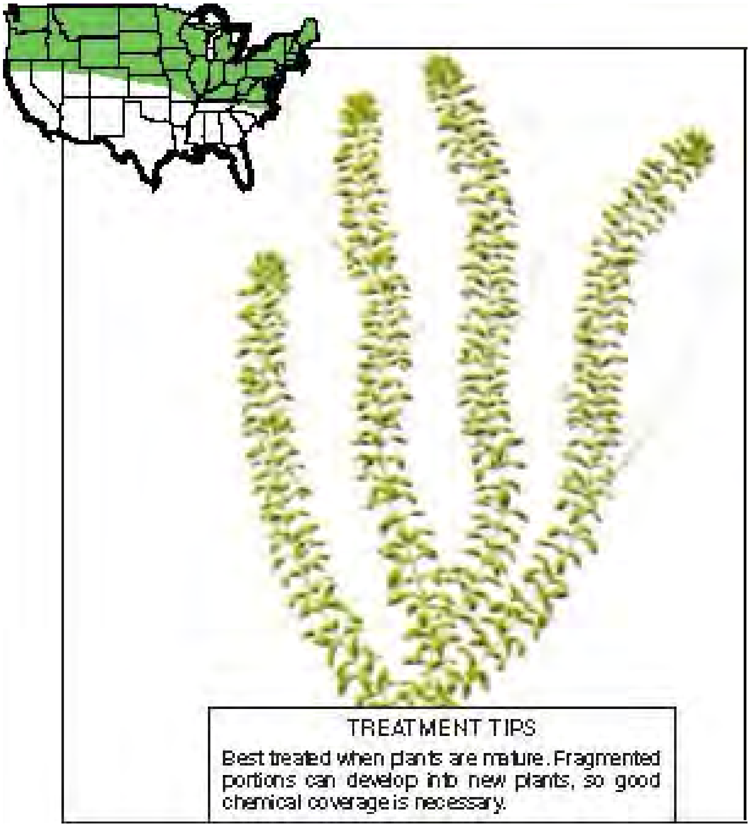
Clogged drainage and irrigation canals are two problems created by prolific Hydrilla growth.

Introduced by the aquarium trade, the spread of Hydrilla has been rapid since the early 1960's. Once thought to be limited to subtropical areas, recent infestations have occurred within temperate areas. Reproduction by turions (winter buds), tubers and fragmentation have made this plant quite competitive. It can thrive under a wide variety of environmental conditions within flowing, stagnant, fresh and tidal water areas. It is tolerant of low light intensities and a wide pH range. Hydrilla has been known to grow to depths of 50 feet (15m) and in bio-mass densities over 130 tons (wet plant material) per acre.

These plants can severely restrict navigation, water flow and fishing. They are of little value to wildlife or fisheries. Dense growths will often cause severe stunting in bass and panfish populations.

Some states have taken the initiative to restrict the importation and transportation of this plant. Arizona and California require that it be eradicated wherever it is found.

Hydrilla plants have dense foliage and can thrive even under low light intensities.



AMERICAN ELODEA *(Elodea canadensis)*

Description: Submersed weed with broad oval leaves, usually four in number, arranged in whorls around the stem. Whorls are compact near the growth tip with spacing between the whorls gradually increasing further down the stem.

Distribution: Usually found in hard water. Common in the Northern and North Central states south to Kentucky and Virginia.

Recommended Control Method: For areas less than 1 acre, tank mix 1 part **Cutrine-Plus** to 5 parts **Weedtrine-D**. Apply at the rate of 1.75 gallons per 1/5 acre. *

OR

For areas in excess of 1 acre, tank mix 1 part **Cutrine-Plus** to 1 part Reward. Apply at the rate of 3 gallons per surface acre. *****

*****Dilute to facilitate even distribution.

Maintenance Control Method: Add **Aquashade** at the rate of 1 quart per acre-foot of water to prevent initial growth or to retard re-growth of plants after chemical treatment.

Alternative Control Methods:

Reward: 2 gallons per surface acre.

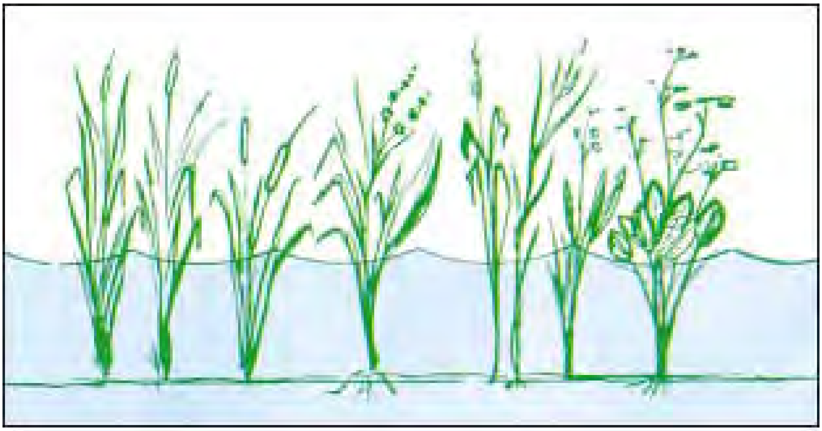
Fluridone: (various liquid or pelletized formulations): see label.

ATTENTION: RECOMMENDATION FACTORS

Many factors have been considered in our recommendations such as effectiveness, toxicity, environmental impact, ease of application and economics. Alternative control methods may be necessary due to water use restrictions (see page 110). Plant distribution within the U.S. is shown on shaded maps accompanying weed pictures. Most of these plants, or closely related species, are found worldwide. Trade names mentioned in this book have manufacturer references in Appendix A, pages 107-109. Alternative Control Methods are listed alphabetically - not in order of preference.

EMERGENT WEEDS

Plants which grow above the water in shallow areas of ponds, lakes, irrigation ditches and rivers are emergent. These plants are generally rigid and are not dependent on water for support. Many are not truly aquatic but can survive in saturated soils or submerged for a considerable period of time.



TREATMENT TIPS

To assure good control, wet leaves thoroughly with a fine spray. Cut off dead leaves at ground level. Re-spray new shoots throughout the season.

CATTAIL *(Typha spp.)*

Description: Long, slender, grasslike stalks up to 10 feet in height. Inhabits wet lowlands and water up to 4 feet deep.

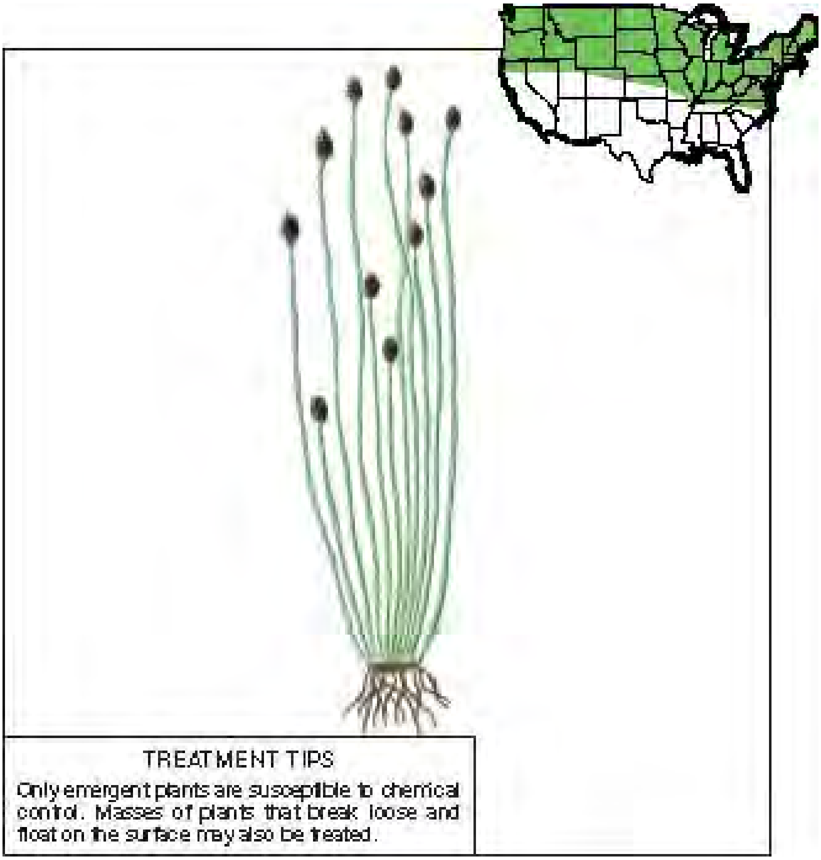
Distribution: Common throughout the United States.

> **Recommended Control Method:** For areas less than 1 acre, mix 6.5 ounces of **Weedtrine-D** with 1 gallon of water plus non-ionic surfactant. 10 gallons of solution will treat 1/10 acre.
>
> **OR**
>
> For areas larger than 1 acre, mix 1 gallon of Reward in 100 gallons of water. Add non-ionic surfactant. Solution will treat 1 acre.

Alternative Control Methods:

Shore-Klear: Mix 1 ounce of Shore-Klear per gallon of water and add non-ionic surfactant in accordance with label instructions. 100 gallons of solution will treat 1 acre.

In northern areas, cut off cattails at ice level during winter. This will sometimes reduce their stands the following year.



SPIKERUSH *(Eleocharis spp.)*

Description: Stems are green and leafless, and range in length from 5 inches (13 cm) to 4 feet (120 cm) with varying diameters. Plant grows in a clump, similar to turf. Mature stems are tipped with a brown to black, scaly, lance-shaped spikelet. Plant reproduces from rootstocks and seeds. Usually found on muddy or sandy shores and in shallow water, but submerged forms do occur.

Distribution: Common throughout the United States in fresh and brackish water.

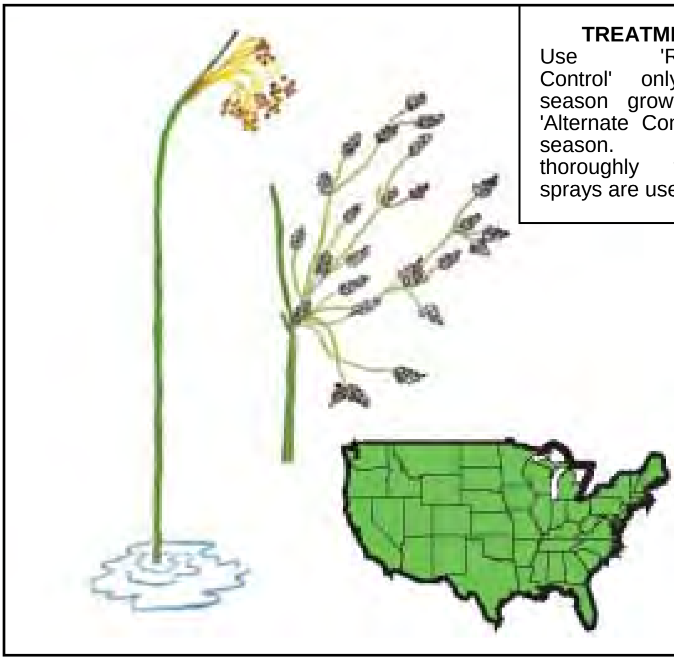
Recommended Control Method: For areas less than 1 acre, mix 6.5 ounces of **Weedtrine-D** with 1 gallon of water plus non-ionic surfactant. 10 gallons of solution will treat 1/10 acre.

OR

For areas larger than 1 acre, mix 1 gallon of Reward in 100 gallons of water. Add non-ionic surfactant. Solution will treat 1 acre.

Alternative Control Methods:

Shore-Klear: Mix 2 ounces of Shore-Klear per gallon of water and add non-ionic surfactant in accordance with label instructions. 36 gallons of solution will treat 1 acre.



TREATMENT TIPS
Use 'Recommended Control' only for early season growth. Choose 'Alternate Controls' later in season. Wet plants thoroughly when liquid sprays are used.

BULRUSH *(Scirpus spp.)*

Description: Long, tall, triangular or round-shaped stem which may or may not have leaves. Cluster of brownish flowers and seeds are located at the end of the stem. Inhabits shallow water along shorelines.

Distribution: Common throughout the United States.

Recommended Control Method: Mix 1 ounce of 2,4-D liquid (see label) in 1 gallon of water. Spray directly on plant. Approximately 75 gallons of this solution will be needed to treat 1 acre of plants.

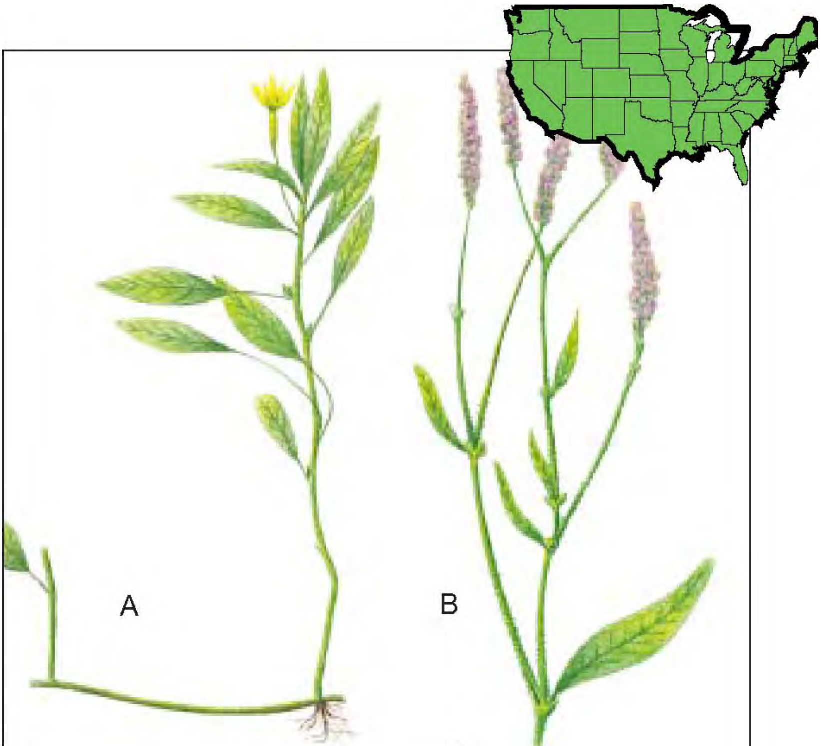
OR

Apply **Navigate** evenly at the rate of 150 pounds per acre of plants.

Alternative Control Methods:

Reward: 1.3 ounces per gallon of water plus non-ionic surfactant.
Shore-Klear: 1 ounce per gallon of water plus non-ionic surfactant.
Weedtrine-D: 6.5 ounces per gallon of water plus non-ionic surfactant.

100 gallons of the above solution(s) will treat 1 acre of plants.



TREATMENT TIPS

Both plants can live on mud flats and moist soils, so care should be taken to treat these areas.

CREEPING WATER PRIMROSE: *(Jussiaea repens)* - Figure A

Description: Plant is generally found in shallow water growing horizontally near the surface. Stem is hollow, red-colored and has numerous leaves. A bright yellow flower distinguishes it from Smartweed.

SMARTWEED, KNOTWEED *(Polygonum spp.)* - Figure B

Description: Erect, rooted herbaceous plant with alternate, oblong leaves. Stem is distinctly jointed. Flowers are small and tightly clustered, and generally pink or rose colored. Plant may be emergent in shallow water or completely submersed with only the flowers above the surface.

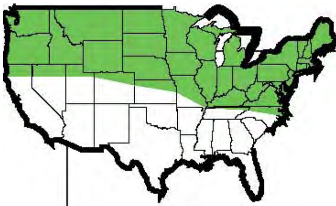
Distribution: Numerous species found throughout the United States.

Recommended Control Method: Apply **Navigate** evenly at the rate of 150 pounds per acre.

Alternative Control Methods:

2,4-D liquid: 3/4 ounce per gallon of water (see label).
Reward: 1.6 ounces per gallon of water, with non-ionic surfactant.
Shore-Klear: 1.3 ounces per gallon of water plus non-ionic surfactant.

75 gallons of the above solutions will treat 1 acre. Spray directly onto foliage.



TREATMENT TIPS

Treat plants before seeds are produced.

PURPLE LOOSESTRIFE *(Lythrum salicaria)*

Description: Plant stems are 2 to 7 feet (0.6 to 2.1 m) in height. These fine-haired stems are stiff and 4-sided. Leaves are arranged oppositely on the stem, usually in pairs but sometimes in threes. Flowers are bright purplish-pink on a spike closely attached to the stem.

Distribution: Western, upper Midwest and Northeastern states.

Recommended Control Method: Mix 1 ounce of Shore-Klear per gallon of water plus surfactant and spray directly onto foliage. Treat after bloom stage. 100 gallons of solution will control 1 acre.

Alternative Control Methods (early season application only):

2,4-D liquid: Mix 1 ounce per gallon of water plus surfactant (see label). 75 gallons will treat 1 acre.

Purple Loosestrife established itself in this marsh and within two years had taken over 25% of the area.

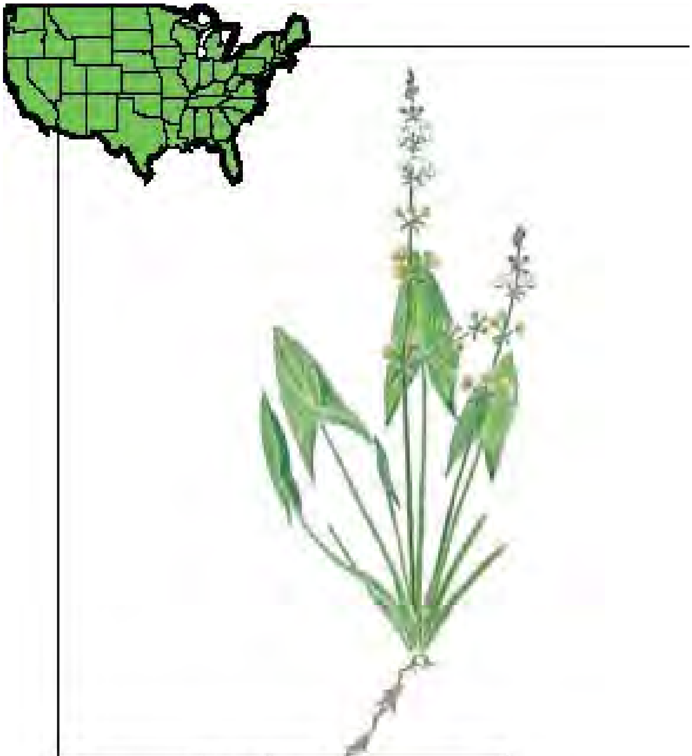
Purple Loosestrife is an extremely aggressive perennial wetland plant introduced from Europe. This exotic has become a serous threat to native, emergent North American vegetation in shallow marshes and along lakeshore areas. Significant spread of the plant has been observed within the past 50 years, even in the sensitive habitats of endangered plant and animal species.

Prolific seed production (up to 300,000 seeds per plant stalk), effective seed dispersal and survival, plus an extensive root system, make it quite competitive. Unfortunately, it has been intentionally introduced in some areas as an ornamental plant for the display of its colorful flowers. Purple Loosestrife can grow in a wide variety of soil types and can withstand dry to saturated soil conditions.

These plants are of very little value to wildlife as food or nesting habitat. Their takeover will eliminate the diverse plant and animal populations required within a stable community.

Some states have taken action to prohibit the sale and distribution of these plants. Early eradication of the plant when it is first spotted is the only effective means of preventing its spread.

Same area as at top of page five weeks after treatment with "glyphosate" herbicide similar to Shore-Klear.



TREATMENT TIPS
Only emergent types will be controled with chemical spray.

ARROWHEAD *(Sagittaria spp.)* - **Common Name:** Duck Potato

Description: Named for its arrow-shaped, emergent leaves, although some may be elliptical in shape. Some forms have ribbon or tongue-like submersed leaves. Underground rootstocks end with tubers. Tiny white flowers are sometimes present.

Distribution: Various species found throughout United States.

Recommended Control Method: For areas less than 1 acre, mix 6.5 oz of **Weedtrine-D** with 1 gallon of water plus non-ionic surfactant. 10 gallons of solution will treat 1/10 acre.

OR

For areas larger than 1 acre, mix 1 gallon of Reward in 100 gallons of water plus non-ionic surfactant. Solution will treat 1 acre.

Alternative Control Methods:

2,4-D liquid: Mix 1 ounce of 2,4-D per gallon of water plus surfactant (see label).
75 gallons of solution will treat 1 acre. Early season treatment only.

Shore-Klear: Mix 1 ounce of Shore-Klear per gallon of water, add non-ionic surfactant. 100 gallons of solution will treat 1 acre. Late season treatment only.

TREATMENT TIPS

Control should be initiated before dense stands of this plant begin to encroach into the water.

PICKERELWEED *(Pontederia cordata)*

Description: Heart-shaped leaves with curving veins parallel to the leaf margin. Flowers are violet-blue and borne on the end of the stem above the leaf. Plants grow up to 4 feet (1.2 m) tall. Reproduces from rootstocks and seeds.

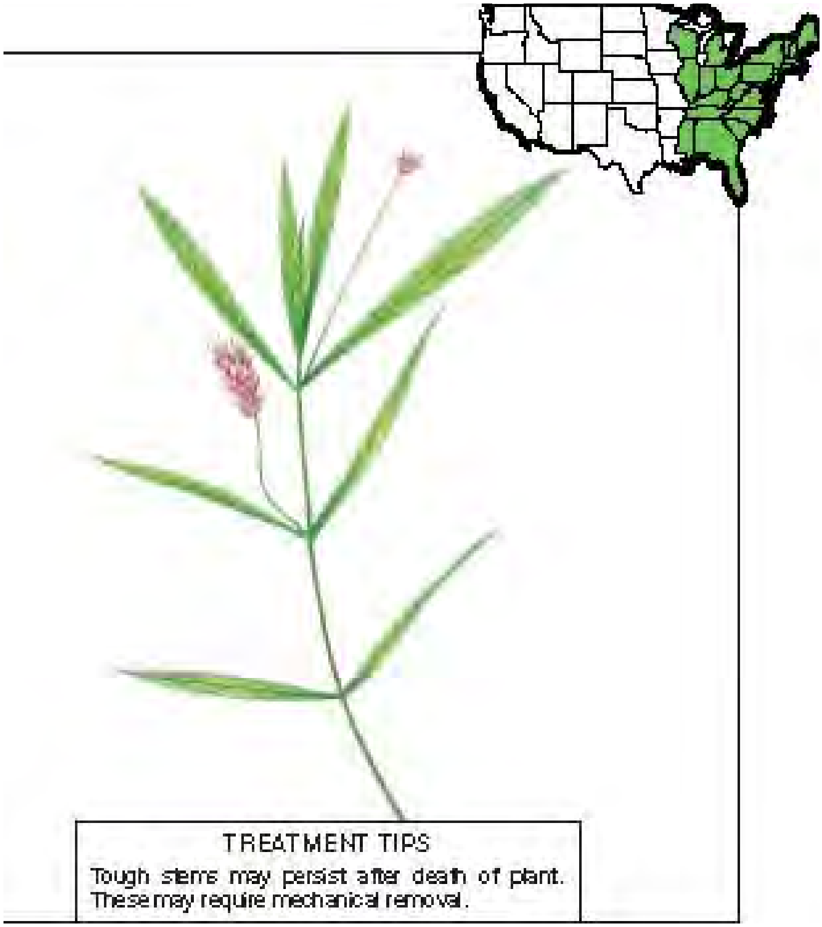
Distribution: Common throughout United States.

> **Recommended Control Method:** For areas less than 1 acre, mix 6.5 oz of **Weedtrine-D** with 1 gallon of water plus non-ionic surfactant. 10 gallons of solution will treat 1/10 acre.
>
> **OR**
>
> For areas larger than 1 acre, mix 1 gallon of Reward in 100 gallons of water plus non-ionic surfactant. Solution will treat 1 acre.

Alternative Control Methods:

2,4-D liquid: Mix 1 ounce of 2,4-D per gallon of water plus surfactant (see label).
75 gallons of solution will treat 1 acre. Early season treatment only.

Shore-Klear: Mix 1 ounce of Shore-Klear per gallon of water, add non-ionic surfactant. 100 gallons of solution will treat 1 acre. Late season treatment only.



WATERWILLOW *(Dianthera americana)*

Description: Leaves opposite and lanceolate***** without a petiole. Perennial plant with purplish flower extending from base of the leaf. Stem is thick and spongy.

Distribution: Eastern U.S., common in shallow water.

> **Recommended Control Method:** Mix 1 ounce of 2,4-D liquid (see label) in 1 gallon of water. Spray on foliage. Approximately 75 gallons of this solution will be needed to treat 1 acre of plants.

Alternative Control Method:

Shore-Klear: 1 ounce per gallon of water plus non-ionic surfactant.
100 gallons of this solution will treat 1 acre.

*****lanceolate: lance-shaped, several times longer than wide, broadest toward the base and tapering to the tip.

STEP #2
DETERMINING
SIZE OF TREATMENT AREA

Once identification of the nuisance plant population has been determined, it is necessary to accurately estimate or measure the size of the intended treatment area. Chemical application rates will be provided on the label in either an amount to apply per surface area (acre) **OR** per volume (acre-foot) of water. One acre is a surface area measurement of 43,560 **square** feet. One acre-foot is a volume measurement of 43,560 **cubic** feet (one surface acre of water one-foot deep).

Shoreline areas, square or rectangular ponds: Determine acreage by multiplying average length (in feet) times average width (in feet) and dividing by 43,560. Use the conversion chart on page 111 for instant calculations.

$$FORMULA: \frac{Avg. Length\,(ft.)\ X\ \ Avg. Width\,(ft.)}{43{,}560} = Acres$$

Example #1: A rectangular pond measures 350 feet long and 200 feet wide. To calculate acreage:

$$\frac{350\ X\ 200}{43{,}560} = \frac{70{,}000}{43{,}560} = 1.6\ Acres$$

Circular Ponds: Determine acreage by squaring the diameter, dividing the answer by 43,560 and multiplying by 0.8.

$$FORMULA: \frac{Diameter\,(ft.)\ X\ \ Diameter\,(ft.)}{43{,}560}\ X\ 0.8 = Acres$$

Example #2: A circular pond measures 235 feet across. To calculate

$$\frac{235\ X\ 235}{43{,}560}\ X\ 0.8 = \frac{55{,}225}{43{,}560}\ X\ 0.8 = 1.27\ X\ 0.8 = 1.0$$

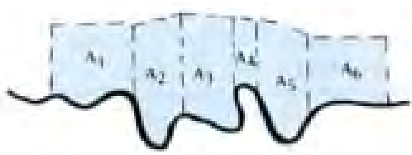
acreage:

Elliptical Ponds: Determine acreage by multiplying overall length (ft.) times maximum width (ft.), dividing by 43,560 and multiplying the answer by 0.8.

$$FORMULA: \frac{Length\,(ft.)\ X\ Width\,(ft.)}{43{,}560}\ X\ 0.8 = Acres$$

Example #3: An elliptical pond is 325 feet long across the middle and 135 feet wide. To calculate acreage:

$$\frac{325\ X\ 135}{43{,}560}\ X\ 0.8 = \frac{43{,}875}{43{,}560} = 1.00\ X\ 0.8 = 0.8\ Acres$$



Where only shoreline treatments are required (for example, a 20 acre lake may only need 5 acres of shoreline treatment), it is necessary to measure shoreline length.

Along relatively straight shorelines, multiply shoreline length (in feet) times the width (in feet) of the treatment areas (see Figure 1).

Along irregular shorelines it may be necessary to roughly divide the treatment area into rectangular sections, determine the acreage of each and add them together to get the total acreage (see Figure 2).

To determine acre-feet of water, multiply the acreage by average depth (in

$$Acre\ \ feet = Acreage\ X\ \ Average\ Depth\,(ft.)$$

feet): In bodies of water having a relatively uniform bottom slope (see Figure 3), average depth can be approximated by dividing the maximum depth by two:

$$Average\ Depth = \frac{Maximum\ Depth}{2}$$

More accurate determinations can be made by taking a number of evenly spaced depth measurements throughout the intended treatment area (see Figure 4). Total the measurements and divide by the number taken. This is also how you determine the average depth for ponds with uneven bottoms:

$$Average\ Depth = \frac{Total\ of\ \ the\ Depth\ Measurements\ Taken}{Number\ of\ \ Depth\ Measurements\ Taken}$$

Maximum Depth
Figure 3

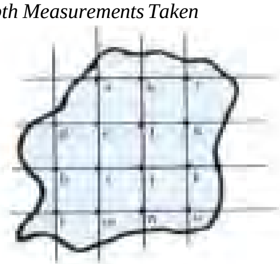


Figure 4

In ponds where water volume (gallonage) is known, acre-feet can be calculated by dividing total gallons by 326,000 (the number of gallons in an acre-foot):

$$Acre\ Feet = \frac{Total\ Gallons\ of\ Water}{326{,}000}$$

Determining acreage and depth of treatment areas can be done very simply if scaled maps are available. Contour maps for many public lakes can be purchased from map companies or obtained from the State. Aerial photos from Regional Planning Commissions, the Soil Conservation Service or other resource agencies are also helpful in measuring larger areas. Grading survey maps or landscape blueprints are often available for larger man-made impoundments.

For calculations for **flowing water systems**, see Appendix G on page 114.

Metric Conversions: Since all labels do not provide dosages in metric measurements, it may be necessary to convert metric length and volume figures to English measures. Conversion formulas are found on page 111 of the Appendix for this purpose.

STEP #3
CHEMICAL SELECTION

The choice of products available for aquatic plant control is somewhat limited as compared to lawn care chemicals, however, the variety is sufficient to solve most problems. In fact, the applicator is often faced with making a choice between alternative products. As stated within the Identification section of this book, "Many factors have been considered in our recommendations such as effectiveness, toxicity, environmental impact, ease of application and economics." For this reason, the Recommended Control Method should be chosen whenever possible. However, Alternative Control Methods may be necessary to use in certain situations. Where a variety of nuisance species are growing within the same area, it is usually not necessary to treat each species separately. Check all recommendations listed under each plant identified and find a common chemical or chemical mixture. Select the higher recommended rate listed.

The product label will specify the information necessary to safely and effectively apply the chemical. It is a violation of Federal Law to use a product in a manner inconsistent with its labeling. Therefore, READ THE LABEL CAREFULLY and make note of the following considerations:

1. **Is the product registered for the intended use?** Product labels will display an EPA Registration Number, indication that they have met the government testing requirements. The sites in which the product may be used (lakes, ponds, fish hatcheries, etc.) will usually be prominently displayed under the product name or listed under 'general information'.

2. **What are the water use restrictions, if any?** Waiting periods for water use (swimming, fishing, irrigation, etc.) may be required for some products following chemical application. This information is found under 'directions for use' or 'precautions' on the product label. A reference chart is proved on page 110 for this purpose, but re-check the product label in case changes have occurred.

3. **What formulations are available?** The formulation refers to the form which the product is in when it is purchased. Recommended products in this book include liquids and granulars. Choosing between a liquid and a granular product with the same active ingredient will usually depend

upon the location of plants to be treated, the size and nature of the treatment area and the types of application equipment available. Generally, liquids are more concentrated and less expensive to use on a per acre basis than granular products. Therefore, they are designed for large or continuous area treatments. Granular products are more efficient and economical to use on growth in deeper water (greater than 4 feet), in small treatment areas (less than 1 acre) or where some minimal flow is apparent.

4. **How does the product work?** Simply stated, chemicals kill plants in one of two ways. Systemic herbicides are taken up by the plant and internally disrupt their growth or metabolic functions. Generally, systemics will travel throughout the system, killing the entire plant. Contact herbicides basically affect the exposed portions of the plant such as leaf and stem surfaces. They may create chemical imbalances, disrupt energy flow or cause physical damage to the plant surfaces.

5. **When are these products best applied?** Product labels will often recommend when a product will work at its optimum. Usually the stage of plant growth, season and/or water temperature will be specified on the product label.

6. **How is the product applied?** Directions for use will recommend the appropriate dilutions, equipment, application techniques, product handling and other instructions necessary for applying the product.

7. **What plants are controlled?** Some considerations might be given to determining whether the product chosen will kill plants other than the main nuisance species. Stands of certain types of vegetation may be desirable. Listings of plants controlled are found on the label. Selective herbicides will kill a limited number of species, whereas broad range herbicides kill a wide spectrum of plant types. By using selective dosage rates or products, it is possible to selectively maintain desirable vegetation while killing off nuisance weeds.

8. **What precautions must be taken in using this product?** Not unlike many household cleaners, medicines and personal care products, aquatic herbicide and algaecide labels provide specific instructions on handling, storage and container disposal. Mainly, these are reminders to use **common sense**. Read these instructions carefully as they are intended to reduce risks and prevent accidents associated with product misuse. A general listing of 'Precautions' is found on page 88.

Some of the recommendations are tank mixes made by mixing two compatible chemicals together prior to application. Advantages of tank mixing might include increased effectiveness, reduced costs and/or simplified application.

Surfactants are also suggested for use with some products. These are soapy materials that help chemicals stick to foliage. They are usually recommended for treating emergent vegetation and are added in small amounts to diluted chemicals. Use of non-ionic, agricultural surfactants such as Cide-Kick® II work best.

Summarized information on each of the products recommended in this book plus others can be found on pages 107-109.

STEP #4
EQUIPMENT SELECTION

The type of application equipment to use will be determined by the chemical formulation to be applied (liquid or granular), the size and location of the treatment area and the type of vegetation to be controlled. The equipment chosen should provide a means of distributing the chemical evenly with a minimal amount of effort.

A hand-crank fertilizer spreader can be used for localized granular applications.

GRANULAR APPLICATION EQUIPMENT

Granular formulations can be spread by hand onto localized growths of aquatic plants along beach areas, boat docks, piers and shorelines. A gloved hand or a scoop works well for sprinkling or broadcasting these materials. Mechanical application of granules in small areas can be accomplished with hand-cranked fertilizer spreaders. For larger areas, gasoline powered forced-air backpack granular spreaders, or boat mounted electric (12v) rotary spreaders effectively treat extensive areas in relatively short periods of time.

An application boat outfitted with two 12-volt granular spreaders.

LIQUID APPLICATION EQUIPMENT

For very small areas, diluted liquid formulations can be poured into the wake of a boat or applied with a sprinkling can directly on infested areas. Hand pumps and boat bailers are adaptable for applying chemicals in localized areas or narrow bands along shore.

More efficient application of liquids is accomplished with the use of sprayers. The 3 to 5 gallon pressure tank sprayers (backpack types) are useful for treating small patches of weeds and algae, especially on emergent shoreline vegetation. Motorized tank sprayers with 10 to 100 gallon capacities are available for larger applications. Smaller wheel-mounted units can be pulled by hand or tractors, while larger skid-mounted systems can be installed in a boat or the back of a pick-up truck. Most are equipped with agitators that continuously mix the spray solution. This makes them especially useful when spray adjuvants such as polymers, wetting agents or spreader/stickers are used.

Specialized equipment is also available specifically for aquatic applications. A system designed by Applied Biochemists (the AB Aquatic Chemical Sprayer) utilizes a 4-cycle pump equipped with a "Y" fitting on the intake. This allows lake water to be drawn in from a 1½ inch hose simultaneously with chemical suctioned in through the adjacent ¾ inch line. A ball valve on the chemical intake line allows adjustment of the chemical to water ratio. Very efficient mixing takes place within the pump and the spray solution is discharged through a 1½ inch hose equipped with an adjustable nozzle. Spray may be set from a fine mist to a coarse stream. Spray booms with multiple drop hoses can be attached to the pump discharge for sub-surface applications on low-growing plants. These systems are portable enough to use from shore or on boats and can efficiently treat up to 100 acres per day.

The AB Sprayer, used by professionals, makes handling and application easy.

The versatility of the AB Sprayer is demonstrated in the following pictures:
(**Courtesy of MARINE BIOCHEMISTS)**

The AB Sprayer is also adaptable for subsurface application.

Large areas can be reached from shore with these sprayers.

They are portable enough to use in a small boat for spraying off-shore or inaccessible areas.

Courtesy of Aquatic Control, Seymour, IN.

Very large bodies of water or inaccessible areas may require specialized treatment equipment. Helicopters and airplanes equipped with boom sprayers are used on long drainage canals, rice fields and reservoirs. Airboats are utilized for treatment of marshy and backwater areas.

Recent technologies have added to the versatility and accuracy of many application methods. The addition of GPS (Global Position System) technology has allowed applicators to track speed, direction, and overall coverage of treatment areas during applications. The use of instantaneous depth determination devices (some as simple as fish finders with depth readings) has allowed for more accurate chemical application rates as well as more accurate marking of littoral zone boundaries (areas of bottom where light penetrates sufficiently to allow aquatic plant growth). Digital flow meters allow for extremely accurate chemical application rates taking a lot of the "guess" work out of equipment calibration. Personal computers have given applicators the ability to integrate these new technologies including the use of spread sheet programs to determine application rates at a given speed and depth. Some application systems go as far as having on-board computers that can automatically adjust chemical flow rates as depths and speeds change. Many large public lake projects require the use of many of these new tools to ensure that the treatments conducted are done as accurately and economically as possible.

The system shown below is a modification of a spray boat utilizing some of the technologies mentioned. A GPS unit is on board as well as a depth finder. A digital flow meter has been installed into the chemical line from a 65-gallon chemical nurse tank. A spread sheet program was designed to give flow rates for different speeds, depths, and transect distances that would be seen during an application. The program can be customized for individual sites and target chemical concentrations. The boat shown has also been modified to utilize the GPS and depth finder for granular applications. The liquid application equipment can be easily removed and two electric (12 volt) granular spreaders can be mounted on the back of the boat.

Spray boat with GPS unit, digital depth finder, digital flow meter and chemical nurse tank.

FLOWING WATER TREATMENT

Specialized equipment and techniques are required for accurate treatment of flowing water systems such as ditches, canals and laterals. Dosing systems must be designed to accurately feed or inject chemical at rates proportionate to water flow such that concentrations remain optimum and consistent throughout the treatment period. Devices used range from simple gravity feed drippers to sophisticated metering pumps integrated with flow meters and computer controlled to adjust dosage as changes in water flow occur.

An electronic chemical metering pump.

Electrically operated metering pumps are available for treatment of re-circulating or flow-through water systems such as irrigation systems, waterscapes or cooling ponds. These units consist of a small diaphragm pump, a chemical reservoir and optional timing device allowing intermittent or continual treatment to be made. Twelve-volt units are available for field use or AC systems can be hard-wired into permanent installations. Gravity fed chemical drip systems are effective treatment devices for race-ways, irrigation canals, laterals and ditches. These systems are equipped with a valve system which continuously equalizes the pressure or head within the drum or chemical reservoir.

With gravity fed chemical systems the chemical is delivered at a uniform rate at a point of turbulence and allowed to distribute itself down-stream. Generally, 3 to 6 hours of contact time is recommended for most chemicals. These systems, placed every 5 to 10 miles along a waterway, can alleviate much of the need for costly mechanical removal of vegetation.

NOTE: Drip systems may not be required if water flow can be stopped in a portion of the canal for 24 to 48 hours and slug dosed with an appropriate amount of chemical. See page 114 for more guidelines.

A simple drip system attached directly to a drum of Cutrine-Plus.

Inverting of aquatic chemicals.

Invert systems or the use of polymers in conjunction with aquatic herbicide applications improve chemical con-tact on plants. These specialized oils and additives thicken the consistency of the spray solutions allowing them to sink and adhere to underwater foliage. This is particularly useful where water movement is a problem. Specialized blending equipment is required for inverting. Standard piston or roller pumps equipped with agitation tanks can be adapted for the introduction of polymers into spray solutions.

STEP #5
APPLYING THE CHEMICAL

Preliminary Considerations: It is worth repeating, at this point, that **before** applying the chemical(s) the following items should have been covered:

The nuisance plant(s) correctly identified.

- The area(s) to be treated accurately measured.
- Necessary permits or approvals obtained.
- The proper chemical(s) chosen, dosage rate(s) determined, and the label(s) carefully read.
- Application equipment chosen and in proper working order.

Re-examine the area prior to treatment. If necessary, for reference, mark off the boundaries with floats or flags. Test run equipment to check for proper operation. If unfamiliar with the use of a liquid sprayer, try a "dry run" using just water. Note the approximate output rate and spray distance.

Test run equipment, calibrate and dilute chemical prior to application.

Dilution and Calibration: Diluting the chemical with water prior to application is necessary in order to achieve even distribution. Do not confuse **dosage rate** with **dilution rate.** The **dosage rate** is the amount of chemical to be applied per unit area. The **dilution rate** is the ratio of water to be mixed with the chemical prior to application to make up a **spray solution**. Dosage rate does **not** change. Dilution rates may be variable. The ratio of water to chemical in a spray solution is mainly dependent upon the output of the sprayer and the speed of the applicator. The normal ranges suggested are a 9:1 to 50:1 ratio of water to chemical, unless the product label specifies otherwise.

For backpack and power sprayers equipped with tanks, estimate how much surface area can be covered with 1 tankful of spray solution. The amount of solution placed in the tank should not exceed the amount required for that area. For example, if a small backpack sprayer has a maximum capacity of 2½ gallons (10 quarts), a 9:1 **dilution rate** would be 9 quarts water to 1-quart chemical. If the **dosage rate** for that chemical is 2 gallons (8 quarts) per acre, it would take 8 tankfuls of the 9:1 dilution to cover the 1 acre area (8 tankfuls X 1 quart per tankful = 8 quarts of chemical). Refer to the Dilution/Dosage Rate Chart on page 113 of the Appendix for specific examples.

For pump systems which use lake or pond water for dilution (the AB Aquatic Chemical Sprayer), pump output should be estimated. To calibrate, place the chemical intake line into a pre-measured volume of water. Adjust the valve to a standard rate of uptake such as 1 gallon per minute (gpm). If the pump output is 50 gpm and the chemical uptake is 1 gpm, the chemical dilution rate is 50:1. Determine how much area should be sprayed in 1 minute based upon this rate of chemical uptake. Refer to the Dilution/Dosage Rate Chart on page 113 of the Appendix.

Do not dilute nor tank mix more chemical than is needed for the immediate area being treated. When diluting, wear gloves and protective eyewear. Avoid splashing. Always add chemical to water, not water to chemical. Be sure mixtures and dilutions are agitated before using. Use clean water to avoid clogging of hoses, screens and nozzles.

Timing of Treatment: Stage of plant growth, water temperature and weather conditions are the three main factors to be considered in determining when to treat. This will vary according to climate. Most chemical applications provide optimum effectiveness when plants are actively growing before flower and seed production. (One exception to this is Shore-Klear, which is best applied to aquatic plants that are "at or beyond early-to-full-bloom stages of growth".)

For **best results**, most chemicals should be applied early in the day under sunny conditions. Water temperatures above 60°F (15°C) are recommended. (One exception to this is fluridone where application is recommended "prior to initiation of weed growth or when weeds begin actively growing".) Biological and chemical activity may be inhibited in colder water or under cloudy weather conditions. Therefore, either reduced control or a much slower kill will result. Prior to application, check all product labels for information regarding this.

Application Technique: Major concerns during application of chemicals are:

- Uniform distribution of the chemical within the intended treatment area.
- Avoiding drift from wind or wave action.
- Safety to the applicator and non-target plants and animals.

Treatments should be made from shoreline outward, generally from shallow water to deeper water. It is not necessary to cover **every** square foot of treatment area since movement of the chemical under piers and rafts will occur naturally. Attempt to apply the proper amount of chemical on the first pass over an area. However, if there is a problem with calibration or an applicator is inexperienced, it is better to treat an area lightly and have to go over it a second time than to overdose on the first pass. It is against the law to exceed maximum-labeled dosage rates, plus, overdosing is a waste of chemical.

Avoid treating under windy conditions or when strong winds are expected within a few hours after application. If there is a light wind, treat with it at your back - never against it. Spray patterns should be adjusted to fairly large, uniform droplets and the nozzle angle should never be tilted more than slightly upward. This will reduce or eliminate drift.

Spray technique may vary depending upon the type of vegetation being treated and the type of equipment being used. Heavy mats of filamentous algae and/or combined masses of algae and plants are best treated with direct high-pressure sprays. This will facilitate breaking up of surface matted plant materials and mixing of the chemical within the water column. Vegetation growing several feet below the water surface, if not treated with granular products, is best controlled by injecting chemical beneath the water surface. This is accomplished by sub-merging the spray nozzle or using a boom apparatus with drop hoses.

Keep spray angle low and use coarse droplets to avoid drift.

For floating-leafed or free-floating plants (water lilies, duckweed, etc.), effective coverage of the leaf surface with chemical spray is required. Spray should be adjusted to fine droplets (avoiding misting). If working from a boat, care must be taken not to wash off chemical from the wake caused by rowing or motoring.

Emergent plants treated with foliar sprays must be thoroughly covered with chemical solution. However, do not wet them to the point where run-off from the surface occurs. Use a flattened (fan-type) spray of relatively small droplet size, if possible. Treat the distant plants first and work "backwards" to avoid disturbing sprayed areas. If spraying from the waterside towards shore, care must be taken not to over-shoot target plants.

Flowing Water: In flowing or re-circulating water systems, drip systems or metering devices must be carefully calibrated so that chemical additions accurately dose the volume of water passing by. Chemical should always be added at a point of strong flow or turbulence to ensure effective distribution and mixing. Calibration should be checked on a regular basis due to potential for equipment malfunction or variable water flow rates. Another approach in canals or raceways is to stop water flow (impound) for a short time (3 to 6 hours), slug dose this section with the correct amount of chemical and start up a drip system when flow is resumed. Number of systems and distance between them is usually a matter of trial and error. Five to ten miles of control can sometimes be achieved from a single point of chemical introduction. See Appendix G, pages 114-117, for additional treatment guidelines.

Application Safety: Safety and effectiveness go hand in hand when using these products. Common sense plus reading and complying with labels will protect the applicator and environment from product misuse. These precautions are as much a part of the directions as are application rates and techniques. FOLLOW THEM CAREFULLY!

READ THE LABEL CAREFULLY!

Handling

- Avoid contact with skin, eyes and clothing.
- Wear protective clothing and eyewear as specified.
- Avoid prolonged breathing of vapors.
- Do not take internally.
- Do not eat, drink or smoke during handling.
- Promptly wash off spills on clothing, skin or equipment.

Storage

- Store in a locked, well-ventilated, cool, dry area away from food, feed, seed and medicines.
- Do not subject to temperature extremes.
- Store in original containers - do not store or use unlabeled products.

Application

- Avoid drift - keep application within the intended treatment area.
- Treat from the shoreline outward to avoid trapping organisms in shallow water.
- In heavily infested small bodies of water, treat only 1/3 to 1/2 of the area at a time - allowing 1 to 2 weeks between successive treatments.
- Keep application equipment functioning properly. If there is a mechanical problem, stop immediately and repair or replace the unit.
- Do not treat during adverse or changing weather conditions.
- Post signs or notify residents if water use is to be restricted for any reason. Some states require pre-posting of public areas (see chart on page 110).

Clean Up

- Clean and check application equipment.
- Flush out spray tanks, mixing barrels, etc.
- Wash up and change clothes.
- Wash clothing and protective equipment separately from other laundry.

Disposal

- Do not reuse empty containers.
- Empty containers should be triple-rinsed and disposed of in accordance with label instructions.
- Do not indiscriminately dump unused material - dispose of in a safe place.

IF IN DOUBT ABOUT USING A PRODUCT, CONSULT YOUR DEPARTMENT OF AGRICULTURE, FISH AND GAME, COUNTY AGRICULTURAL EXTEN-SION AGENT OR THE MANUFACTURER.

STEP #6
FOLLOW-UP

The degree and duration of control desired plus the climate, weather conditions, species present and water quality will determine the **frequency** of chemical applications required. Follow-up treatments to control plants in areas missed by the initial applications or for control of re-growth may be required from 10 to 30 days following the first application. It is wise to have sufficient herbicide on hand to re-treat 1/4 to 1/3 of the original area. Touch-up work can often be accomplished by spot treating with granular products. Re-growth, which occurs in the same season, should always be examined to determine whether a species change has occurred. It is not uncommon for different mid-summer plants to replace species that infested an area in spring. Alternative chemical or dosage rates may be required to treat late season growth.

Where algae growth is a recurring problem, maintain a suitable supply of chemical for several treatments. Typically, algae will be actively growing during the months when water temperatures are above 60°F (15°C). Frequency of application will normally range from 3 to 6 weeks apart. Warmer water temperatures, high nutrient concentrations and intense sunlight will promote algae growth.

Although conditions may vary from year to year, with some experience it is possible to predict the annual chemical treatment requirements of a body of water. This is why accurate record keeping is important (see report format below). To prevent problems from getting out of hand, stock the necessary chemicals so they are available at the first signs of trouble.

TREATMENT REPORT

LAKE OR POND NAME: ______________________________ DATE:

TOTAL AREA TREATED: ______________________________ TIME:

TREATMENT

Chemicals	Amount	Nuisance Plants	Area/Depth
____________	________	____________	
____________	________	____________	
____________	________	____________	

Personnel	Equipment
______________________	Boat:
______________________	
______________________	Sprayer:
______________________	Other:

NOTES

Weather Conditions: Wind: ________ Direction: ________ Air Temp. _____°F.

Sky:

Water Conditions: Waves: ________ Turbidity: ________ Temp. _____°F.

Observations:

Provide Sketch Map Report By:

POST-TREATMENT
Questions & Answers

When will I see results?
Usually, plants begin to show signs of weakness or die within 2 weeks. Signs include discoloration, elongation or wilting. Filamentous algae often turns pale yellow or whitish within 3 to 4 days. Planktonic algae disappears in 24 to 48 hours. Dead plants with tough stems and sturdy root systems may remain standing until wind or waves break them up.

What happens to the dead plant material?
Decaying plants and algae usually sink to the bottom after they die. Occasionally, however, plants with weak stems may break loose and float temporarily. Microscopic organisms in the water break down (decompose) plant materials leaving a fine residue of silt that settles to the bottom.

Will my water quality change?
When large masses of vegetation decay, recycling of the plant materials occur. Some nutrients end up in sediment while others enter the water column. Some temporary decrease in dissolved oxygen levels may occur.

How long will control last?
Many weed species can be controlled for an entire season with a properly timed, single treatment. Herbicides do not kill seeds, and some do not get into root systems. This can result in a re-growth of plants requiring touch-up later in the season. Algae will generally require treatments 3 to 6 weeks apart during the season because of their ability to reproduce rapidly.

Will I have fewer plants next year?
Once well established, nuisance aquatic plants will typically continue to be a problem each year. Some reduction in weed beds may occur the following year if treatments were made before seed production. Changes in dominant species or plant abundance is more likely to occur due to environmental factors such as water clarity, nutrient concentrations and weather factors. Different herbicides may be required.

Do resistant plants establish themselves?
There is some evidence that treating too often, year after year with the same chemicals, may result in the establishment of an unaffected species. This may require changing chemicals, dosage rates, using a combination of chemicals, or employing a combination of techniques (aeration, nutrient deactivation, dilution, etc.).

What happens to the chemical that is put into the water?
Products recommended in this book do not remain in the water in their original state for extended periods of time. Chemical and biological actions break down (biodegrade) these compounds into simpler, natural basic compounds. These are recycled within the environment. They do not build-up as residues in fish nor in the fish food chain.

What are common reasons for failure?
Occasional control failures can occur, usually due to one or more of the following reasons:

1. Not reading the product label and following directions.
2. Misidentification of the plant resulting in use of the wrong chemical.
3. Miscalculation of the treatment area resulting in the wrong dosage.
4. Adverse weather conditions (high winds, rain storms, etc.) during or immediately following treatment.
5. Water conditions (high turbidity, low temperatures, etc.) physically or chemically interfering with the herbicidal action.
6. Weed re-growth or appearance of new vegetation.
7. Improper timing of treatment - too early or too late.
8. Rapid water exchange causing chemical dilution.

LAKE AND POND MANAGEMENT

While previous sections of this book deal specifically with the practical symptomatic approaches to controlling aquatic plants, other considerations may be involved in managing a body of water. Some understanding of watersheds, pond construction, water chemistry and fisheries biology can be useful in protecting, renovating and/or enhancing the water resource. It must be kept in mind that any biological, chemical or physical alteration made in the aquatic environment will have inter-related impacts.

Therefore, it is important that any management technique implemented be done carefully and with forethought as to what factors may be affected. While some bodies of water can support multiple-use activities, others are limited to specific purposes. The ideas presented here are intended to assist in maximizing their recreational, functional and/or aesthetic value.

POND CONSTRUCTION CONSIDERATIONS

PLANNING

Careful planning in the design and construction of a pond can prevent many future problems. It is best to consult with professionals such as the Soil Conservation Service, Agricultural Extension, State Fish and Game Department and private engineering consultants to ensure both the feasibility and legality of construction in the area being considered. In some states, financial assistance may be available under water conservation or wildlife protection programs.

Ponds should be built in well-vegetated watershed areas.

SITE SELECTION

The location and size of a pond will be dictated by the type of landscape (topography), soil structure, quantity and quality of water sources. These factors will determine whether a pond will be an excavated (tank-type) or an embankment (dammed) impoundment.

Ponds can be constructed where groundwater supplies are near the surface, where well water supplies or springs are available, in low-lying areas where run-off from the surrounding watershed (drainage) area is sufficient, or at the foot of streams. Some ponds may have to be constructed in a specific area out of necessity for storm water retention, fire protection or decoration, thus precluding some of the factors that might be considered in choosing an ideal site. In these situations, special measures may have to be taken such as using pond liners or sealants, providing supplemental water sources, or designing artificial water drainage systems.

Stabilizing shorelines is important to prevent erosion.

Generally, it is not recommended (nor legal) for individuals to dam permanent streams. Groundwater supplies generally offer the highest quality water. However, if surface water sources are used, they should come from a well-vegetated watershed area.

Supplemental water sources, such as wells, may be necessary in some areas to maintain water levels or to periodically add fresh water. Water can be pumped in through standpipes to help function in aerating the water.

Soil composition of a pond bottom and banks should be of a nonporous material such as packed clay to prevent seepage. This is particularly important in dams. If suitable materials are not native to the area, commercially available clays such as Bentonite can be used.

Construct shorelines with a minimum of 1:3 slopes to discourage vegetation growth. A sufficient portion of the pond should be at least 10 feet deep. This will help prevent both aquatic plant growth and the potential for winterkill of fish under the ice in northern areas.

Install a drainpipe in the pond bottom, if feasible. This will allow lowering of water levels to repair leaks, re-excavate, or to remove trash fish.

Sealing a pond with Bentonite clay.

Spillways are necessary in embankment ponds and might also be considered for excavated ponds. They provide an outlet for excess water that would otherwise erode shorelines or cause property damage from flooding. Determining the design, size and construction of dams and spillways are tasks best left to professional construction engineers.

A cement spillway carries away excess water.

CONSTRUCTION

In constructing a pond, it is advisable to remove all topsoil, brush and trees from the basin. Trees within 25 feet of the pond's edge should also be removed to prevent leaf litter from accumulating. Topsoil can later be used to cover banks before sodding or seeding with a fast-establishing perennial grass.

The following are several helpful hints to be considered. A narrow path of mounded soil near the pond's edge (called a berm) will serve to trap eroded materials, which might otherwise wash into the pond. All dams and embankments surrounding the pond should be free of stumps and brush to prevent leakage as this material decomposes. A filter bed of rock and rough gravel can be placed in areas where water is channeled into the pond. Finally, if water from the watershed is more than sufficient to maintain the pond level, a diversion ditch can be constructed to prevent some of the water from entering.

LEAKAGE

Seepage of water from a pond may become a problem when soils are too porous or are improperly compacted. Sealing of a pond may become necessary. Techniques include compaction, application of clay sealant, addition of chemical additives or installation of waterproof linings. Consult a soil expert or consultant to determine the best method.

By following the practical management and maintenance procedures described elsewhere in this book, a pond can offer many years of recreational enjoyment or functional use. Problems should be dealt with as they develop to avoid costly renovation.

UNDERSTANDING WATER QUALITY

Surface water is never found in a pure state. Even the cleanest lake or pond will contain various concentrations of dissolved gases, salts, minerals, metals and organic compounds. Most waters are teeming with microscopic plants, animals and bacteria along with suspended sediments and organic matter. Water quality is determined by the collective interaction of these chemical, physical and biological components. Some of the more important water quality parameters, and their relation to the "health" of a lake or pond, are discussed below. Corrective measures for some problem situations are also included.

Dissolved oxygen concentrations are an important gauge of existing water quality and the ability to support a well-balanced aquatic animal and plant population. Through the natural mechanisms of aquatic plant photosynthesis and surface absorption, oxygen is constantly being added to the water. At the same time, there is a continuous consumption of oxygen taking place throughout the water column by fish, zooplankton (the microscopic animals upon which small fish feed), aquatic insects, snails, crayfish and a diversity of other swimming and bottom-dwelling organisms. Competing for this same oxygen are multitudes of bacteria which utilize oxygen in the decomposition of organic materials (dead plants and animals, fertilizer, animal wastes, run-off water contaminants, septic seepage, etc.) entering or within the system. Aquatic plants may compound the oxygen balance problem by using, instead of producing, oxygen. This occurs during the night, under extended cloudy periods or beneath snow and ice cover.

Severe vegetation problems can cause oxygen depletion and fish mortalities.

As a result, variations in oxygen content occur from the surface to the bottom and also from day to night. In addition, seasonal variations occur which affect chemical and biological cycles within the entire water body. When water temperatures are equal throughout the water column in spring, surface and bottom waters will mix. This distributes dissolved oxygen vertically and horizontally, virtually equalizing concentrations throughout the water. As the surface warms by the heat of the sun, layering begins to develop. Cooler, denser water is trapped at the bottom while lighter, warmer water remains near the surface. This temperature-based layering, known as **thermal stratification**, creates a natural barrier to vertical mixing within the water column. Within or near the bottom sediments, dissolved oxygen concentrations may become depleted. Meanwhile, surface water remains oxygenated through absorption and horizontal mixing by wind action. Fish and other beneficial life forms are then restricted to this surface stratum.

The cooling of the surface water in fall will eventually break down this stratification. This again allows complete mixing of surface and bottom waters and re-oxygenates the water column before the onset of winter. In areas where an ice cover forms, absorption of oxygen from the atmosphere ends and virtually all mixing comes to a standstill. Under the ice, life becomes totally dependent upon existing dissolved oxygen and that produced by surviving vegetation. If thick ice or snow cover shuts off sunlight, plants will die or respire and become oxygen users instead of producers. When oxygen demand exceeds supply, a winterkill of fish and animal life occurs.

Generally, a minimum of 5 mg/L dissolved oxygen is required to support warm water fish and 6-7 mg/L for cold water species. Dissolved oxygen is also essential to the efficiency of the decay process on the bottom. If oxygen is depleted, microbe populations switch from aerobic (with oxygen) to anaerobic (without oxygen). The by-products of anaerobic decomposition are noxious, malodorous gases such as hydrogen sulfide ("rotten egg" odor) and methane. Due to inefficient breakdown of dead plant and animal materials under these conditions, a black muck or sludge will form on lake and pond bottoms.

Main components of a compressed air system.

Aeration equipment can be installed to overcome oxygen deficiency problems. Benefits of proper aeration include:

- prevention of winter/summer fish kills
- fish habitat promotion/expansion
- elimination of noxious anaerobic gas build-up
- improved water quality
- reduction of certain nutrient problems due to oxygenated benthic (bottom) interactions
- increased decomposition of organic materials in an aerobic bottom layer
- complete de-stratification of the water column equalizing temperatures and oxygen concentrations throughout the lake or pond.

Normally, this is only practical in ponds and small lakes. Aeration of large bodies of water can be difficult, and if the installed system is not sized properly, increased nutrient cycling may occur.

Numerous types of systems are commercially available including:

- compressed air systems (systems pump air from shore through tubing to diffusers on the bottom)
- bottom and floating horizontal aerators (force water movement horizontally)
- floating vertical aerators – fountains (pumps water vertically into air).

Of primary consideration are the energy efficiency and the rate by which oxygen is distributed throughout the water column. Vertical water pumping systems, while decorative, are costly to run and are slow to disperse oxygen in larger bodies of water. Compressed air systems provide an effective, cost-efficient and flexible means of adding oxygen while moving and mixing the water. Horizontal aerators have similar energy requirements to those of vertical aerators, but have the ability to mix water in shallow stagnant areas where other systems may be ineffective.

Sizing and placement of equipment may vary with the size, depth and configuration of a body of water. In addition, timing of installation must be considered to avoid too rapid of a change in conditions. Therefore, it is recommended that lake and pond owners contact the manufacturer or a consultant prior to installation.

It should be noted that aeration is not in itself effective in controlling aquatic weed and algae growth. The only benefits in this regard may be a shift in species from noxious blue-green algae to green algae, and oxygenated benthic interactions may prevent certain nutrients key to aquatic growth from re-entering the water column. Note that any nutrient reduction may not be sufficient to eliminate aquatic growth problems and will not prevent nutrient recycling through rooted aquatic plants.

Water fertility is determined by the amount of dissolved nutrients (mainly nitrates and phosphates) available within a body of water. The productivity or degree of vegetation growth is directly related to water fertility. Lakes and ponds with high nutrient levels are called **eutrophic** and the process of nutrient enrichment is called **eutrophication**. At any point in time, nitrogen and phosphorous might be found within bottom sediments as a component of plant and animal tissue or dissolved within the water. Seasonal variations are common, as these nutrients are recycled within the aquatic environment from one form to another.

Controlling outside sources of nutrients plus reducing those already within a lake or pond is a long-term idealistic approach towards eliminating the main cause of overabundant plants. Attempts at doing this have been met with mixed success. Limiting nutrient input from sources within the watershed can range from making a few simple alterations around a pond to redesigning sewage systems and agricultural lands along drainage systems entering a lake (see Preventative Maintenance Check List, page 105).

Microbial bio-augmentation (see page 23) techniques can be utilized to try to establish an additional aquatic food web component to limit nutrients available for aquatic plant growth. By limiting soluble phosphorus and nitrogen, the amount of algal growth may decrease and a shift of species may occur. In addition, the reduction of soft organic sediment that may occur would limit the nutrient sink utilized by rooted vegetation. Success using this method has been seen by applicators, but only in conjunction with proper management of the surrounding watershed (see Preventative Maintenance Check List, page 105) and proper aeration (discussed under dissolved oxygen).

Technology is available for reducing or inactivating dissolved phosphate through the addition of 100 to 160 lbs. of aluminum sulfate (alum) or 40 to 120 pounds of ferric sulfate per acre-foot. These chemicals precipitate or are lost from solution, taking available phosphates with them. The amount required is dependent upon the existing concentration of phosphorous and the pH of the water. Actual dosages are best determined by laboratory analysis. Overdosing could result in drastic pH change and a loss of fish life. Professional assistance is encouraged.

Removing nutrients from the water column will have a particular effect upon reducing algae and free-floating plant growth. A more limited effect will be seen on rooted plants since they can derive nutrients from the sediment. As an additional benefit, alum and ferric sulfate will act as water clarifiers by removing particulate materials suspended in the water column.

Turbidity refers to a measure of the relative clarity of water. Turbidity or muddy water is often caused by suspended silt or clay particles, which diffuse or scatter light. As a result, light does not penetrate through the water column and the water appears unclear. This should not be confused with discolored water, which sometimes results from dissolved materials such as organic acids from leaf litter.

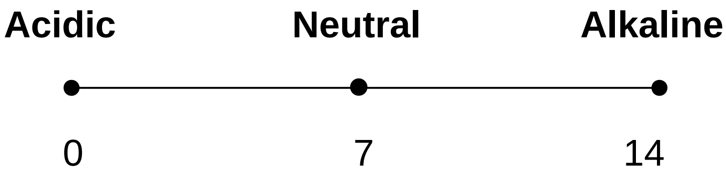
Erosion of soil along shorelines or within the watershed is a primary contributor to excessive turbidity. Poor construction or farming practices is often to blame. Wind and wave action or the disruption of bottom sediments by carp and bullheads can create or contribute to the problem.

High turbidity will reduce light penetration and retard bottom plant growth. It may also have the negative impacts of irritating fish gills and impairing spawning and predation success. Turbid water is typically poor for game fish production and undesirable from an aesthetic and recreational standpoint.

Microbial bio-augmentation (see page 23) methods may be able to reduce suspended organic solids by the microorganisms breaking down the material into gases and/or bio-mass. Proper aeration (discussed under dissolved oxygen) and proper watershed management practices (see Preventative Maintenance Check List, page 105) should be in place. This method will not have affect on inorganic suspended solids such as clay.

Application of flocculants such as ferric sulfate or alum (discussed under water fertility) or use of agricultural lime or gypsum at 1,000 pounds per surface acre will help clear water. It is best to add these materials gradually to avoid rapid environmental changes. Some experimentation or consultation with professional help is also recommended. Turbidity will be a recurring problem unless the source of the sedimentation is corrected.

Alkalinity and pH are important measures of the "chemical balance" within water. The types of aquatic life present are in part governed by these two parameters. Alkalinity is a measure of buffering capacity or the ability to tolerate the addition of acids or bases without appreciable change in pH (a measure of the water's relative acidity). Water's relative acidity (its pH) is based upon a logarithmic scale of 0 to 14 with 7 considered neutral, measurements less than 7 are acidic and measurements above 7 are alkaline.



pH Scale

Generally, pH and alkalinity are dictated by the chemical make-up of bottom sediments, surrounding soil and water entering the system through run-off or rainfall. The interrelationships between carbon dioxide, bicarbonates and carbonates (a process too complex to explain here) determine pH and alkalinity. Suffice it to say that waters in limestone regions or where minerals are easily dissolved will contain carbonates and bicarbonates. These are typically termed hard water areas and will be alkaline. Lowland bog areas, mountain lakes or those located in bedrock areas will contain free carbon dioxide. These are referred to as soft water areas and waters will be near neutral to acidic.

Most freshwater life prefers a pH range between 6.5 and 9.0. Different organisms have varying tolerances. Relatively rapid changes in pH can occur in soft water and are typically low in production of aquatic life. At the other end of the spectrum, higher alkalinities are associated with increased productivity. Algal blooms can serve to raise pH by utilizing the free carbon dioxide being absorbed from the air.

Raising or lowering pH in a body of water is done on rare occasions. Some acid lakes affected by acid rain have had their pH raised through the addition of lime. This is a temporary solution and may require maintenance applications. Newly dug ponds are occasionally limed to establish a higher potential for fish production. These management techniques are not recommended unless under the guidance of an expert.

Coliform bacteria are important indicators of contamination from animal and human wastes. Determining their presence is particularly important in waters used for swimming, domestic use or drinking. High levels of these bacteria raise concern over the potential existence of pathogenic (disease-type) bacteria and viruses. Since they are short-lived organisms, their presence indicates recent contamination.

State and federal guidelines have been established that determine what levels are considered safe for body contact, drinking or domestic use. Water samples must be collected in sterilized bottles and tests should be run by a certified laboratory. Multiple tests are done at varying frequencies to crosscheck results. Frequent occurrence of high levels may require closing of swimming areas and the need to correct septic or sewage discharge sources.

Water pollution can destroy recreational areas.

Pollutants and contaminants from industry, agriculture and other sources can adversely affect water quality. Input can be airborne, contained in surface run-off and groundwater, or found within direct discharges. Examples which have received recent attention include PCB's (polychlorinated biphenyls), dioxins, heavy metals (mercury, arsenic, lead, etc.), hydrocarbons and pesticides.

Some pollutants can be detrimental to aquatic life and may even pose human health hazards. They can accumulate within bottom sediments or may be recycled within the food chain. A build-up can occur within the flesh and tissues of gamefish, making them unfit for human consumption. Other contaminants will be directly toxic to the organism itself or cause poor growth and reproduction.

The watershed and direct, in-flowing water (rivers, ditches, pipes, etc.) must be examined closely for potential sources of contamination. Use of agricultural pesticides and fertilizers on surrounding land must be done with care. Herbicides, not **specifically** labeled for **aquatic use** sites, should **never** be introduced for weed control in a lake or pond. If specific contaminants are suspected within the water or sediments, sophisticated testing with highly sensitive equipment at a reputable laboratory is advised.

UNDERSTANDING FISH MANAGEMENT

Fisheries management is the science of manipulating fish populations within a body of water in order to achieve maximum desirable production. Maintaining these populations requires that the species present must survive, grow and reproduce. The typical objectives for managing fish are for food and/or recreational resources.

Of primary concern is providing a suitable environment to meet the needs of the fish species' habitat and food requirements. Acceptable water quality is extremely important. Most of these parameters and requirements are discussed in the sections covered under "Understanding Water Quality" (pages 95 to 100). Closely related to this is the matter of water temperature. Fish are roughly categorized into warm water, cool water and cold water species. A partial listing is provided below:

Warm Water	Cool Water	Cold Water
Largemouth bass	Walleye	Trout
Striped bass	Smallmouth bass	Salmon
Sunfish (bream)	Yellow perch	
Crappie		
Catfish		

Most warm water species will do well within a wide range of water temperatures from ice-covered waters to beyond 80°F, although growth will be slower in cooler water. Cool water fish prefer temperatures ranging into the upper 60's (F°). Cold water varieties are best suited for temperatures below 65°F. Within ponds or lakes, which thermally stratify, species from several of these groups may do well.

Other important considerations include providing hiding places for young fish and suitable substrate for spawning. These requirements vary widely with species, therefore, knowing the life history of each is important. Controlling aquatic plants to acceptable levels, as discussed in the first part of this book, is of primary concern in limiting cover. Too much vegetation will lead to an overabundance of small, stunted fish. Proper bottom materials (sand, gravel, etc.) or plant stems may be required for depositing eggs. In some bodies of water, cover or bottom materials may have to be provided. Structures, called "cribs", consisting of rock piles, fallen trees, or bundles of branches are sunk into the water for this purpose. Artificially constructed reefs and gravel bars may also be installed.

Decisions to stock fish must be based upon the conditions of the existing habitat and particularly take into account what fish are already present. Any given body of water will have a certain carrying capacity or maximum production. Simply adding fish to an existing population is rarely successful, unless there is an excess of food and unoccupied habitats. Suitable numbers of forage (food) fish must be present if larger predator fish are to survive. Choice of species and stocking ratios will vary geographically and by environmental conditions. Therefore, contacting the biologists at local fisheries or hatchery operators is recommended. Some may be able to provide a fisheries management survey to determine the existing balance and condition of the population.

Fish shocking is one means of assessing an existing fish population - photo courtesy MARINE BIOCHEMISTS, Mequon, WI

Avoid the mistake of expecting to control a stunted panfish population by simply adding a number of large predators. (Hybrid or non-reproducing sunfish have become a popular alternative to avoid problems with overpopulation of stunted panfish). Similarly, do not assume that a gamefish population can be established within a body of water overrun with carp or rough fish. Either of these situations should be remedied with an eradication program of existing fish stocks. This can be done through draining or use of a fish toxicant such as Rotenone. If fish are stocked, obtain them from a reputable hatchery. Make certain that they are free of disease and healthy upon their arrival. Handle them carefully and as little as possible. The temperature difference between the holding water and the lake or pond should not exceed 10°F. If it is, fish must be gradually acclimated.

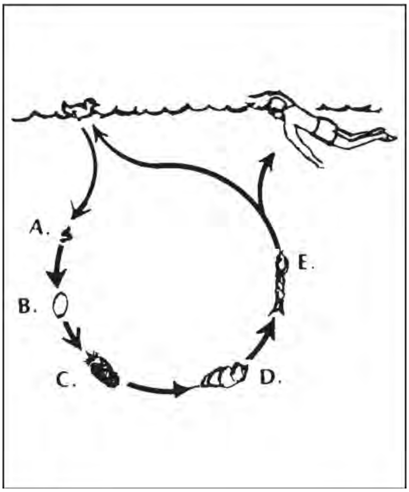
The amount of fishing pressure required to sustain a balanced population will vary. Panfish can usually be caught when they reach desired size. Intensive removal of panfish may be required to avoid stunting problems. Similarly, size and catch limits might be imposed upon larger fish to ensure their numbers. However, it is best not to remove predator gamefish until after they spawn (approximately 3 years after stocking).

Except under exceptionally sterile conditions or where extremely high productivity is desired (such as aquaculture ponds), fertilization and feeding programs are not recommended. Properly managed waters contain enough fertility to support good fish growth. Addition of more nutrients may only lead to undesirable and uncontrolled weed and algae growth.

Keep records of fish stocking and a creel census of what has been caught. Examine fish periodically for signs of stress or disease. Check water quality regularly for signs of trouble. Consult an expert if problems are suspected.

Records of types, sizes and numbers of fish caught are useful information to a fisheries biologist.

Swimmer's itch, a skin condition caused by a nuisance parasite associated with snails, can cause problems in swimming areas. In one phase of its complex life cycle, the parasite is an actively swimming organism called a cercaria. The cercariae (pl.) can penetrate the outer layer of skin on bathers and cause red welts, itching, and general discomfort. Showering or thorough drying of the body immediately after swimming can reduce the chances of developing irritation. Control of these organisms involves elimination of both the host snails and the free-swimming cercariae. Mobility of these organisms is somewhat limited, therefore, treatment can be confined to beaches and adjacent areas having high snail populations. **Check with local regulations and state agencies prior to any proposed treatment program**. Treatments may be allowed in certain situations for health reasons.



Life cycle of swimmers' itch cercariae:
(A) blood fluke carried by water bird
(B) egg
(C) miracidia
(D) snail host
(E) cercaria seeking host.

Burrowing animals can damage shorelines and cause leaks in dams and spillways. Muskrats are often the main offenders. Lining banks with stone will discourage their burrowing. If the problem becomes severe, live traps placed in culverts or near their burrows are an effective and humane way of catching and transporting these animals to other areas. Wire netting can be placed across pipes to prevent nesting. Elimination of cattails and other succulent emergent plants, their favorite foods, is also a deterrent.

Turtles, although not a severe problem, can become unwanted pests in fishing areas. They rarely threaten fish populations as they consume mostly dead or dying fish, insects or bottom organisms. If they become a nuisance by eating fish off stringers or taking your bait, floating live-box traps or turtle nets are available. The best baits are dead fish, chicken entrails or liver. Snapping and soft-shell turtle meat is a delicacy.

Leeches, commonly referred to as bloodsuckers, frequently inhabit lakes and ponds. Actually, very few species feed upon the blood of warm-blooded animals. Most will host upon dead or dying animals and small invertebrates. Some species are parasites to fish.

Leeches can be temporarily controlled with the same treatment used for swimmers' itch control (see page 103). It is more advisable, however, to stock hybrid sunfish or bass. These fish are natural predators to these organisms. Baiting with fresh pieces of meat tied to a string and disposing of those captured has met some success. Domestic ducks will also randomly capture them as food.

Too many waterfowl on a pond can lead to trouble with water quality.

Geese and ducks may be enjoyable to watch, however, in large numbers they can create a nuisance. Waterfowl waste on piers, rafts and beaches create an unsightly health hazard. Droppings will also act to fertilize ponds, possibly introduce swimmers' itch parasite, and bring in new weed seeds. Starting with a few ducks or geese may be tolerable, but this often multiplies into a few too many.

Do not encourage their visitations by feeding them. Plastic swans, black silhouettes or even flags have worked to frighten them off. In severe cases along migration routes or areas where they attempt to over-winter, use of air cannons have effectively chased them back to the wilds.

Predatory water birds such as herons, kingfishers, mergansers and others may damage fish stocks, particularly in commercial aquaculture facilities. However, in natural ponds these birds usually perform the function of keeping fish populations in check. Generally diseased, weakened or stunted fish are primary targets.

In hatchery ponds where no predation is desirable, netting can reduce the problem. If significant loss of gamefish populations is noted, it is likely a sign that more protective cover is needed. Leave portions of the water vegetated, particularly in deeper water where birds will have difficulty feeding.

PREVENTATIVE MAINTENANCE CHECK LIST

NUTRIENT AND SILT CONTROL:

- ☐ Do not fertilize grounds sloping towards the water. Fertilizer will eventually end up in the lake or pond.
- ☐ Maintain a properly functioning septic system. Seepage can be detected through the use of dyes flushed into the system.
- ☐ Dispose of wastes (leaves, grass, fish entrails, garbage, ashes, etc.) away from the water. All of these materials can serve to increase the nutrient concentrations.
- ☐ Allow a "buffer zone" (strip of grass or natural vegetation) to grow around the shoreline. This will help stabilize banks, reduce erosion, provide an aesthetically pleasing landscape, and retain some nutrients that would otherwise enter the water.

SHORELINE MANAGEMENT:

- ☐ Plant native vegetation that blends in with the surroundings. This will encourage a diversity of wildlife.
- ☐ Protect shorelines from erosion and undercutting. Use rock lining (rip-rapping), terracing or seawalls.
- ☐ Fence out livestock to prevent them from entering the water.

FISH MANAGEMENT:

- ☐ Never randomly stock fish. Introduction of fish should be carefully planned in terms of species, sizes and numbers according to the size, water quality and production potential of the pond.
- ☐ Do not introduce rough fish (carp, suckers, etc.). Never discard unused minnows into the water.
- ☐ Watch for signs of unbalanced fish populations such as overabundant small fish, too many fish of one size class, or under-nourished fish.
- ☐ Do not over fish under-populated gamefish ponds (bass and trout) or under fish over-populated panfish ponds.
- ☐ Do not over feed fish if a supplemental feeding program is used.

SAFETY AND EDUCATION:

- ☐ Locate life-saving equipment at the water's edge. This should include a ring buoy with sufficient rope and a long pole.
- ☐ Designate swimming areas with signs or floats and post warnings concerning deep water, drop-offs, underwater obstructions, etc.
- ☐ If sewage contamination or run-off from livestock areas is suspected, have the water tested for bacterial contamination.
- ☐ Always carry life preservers in boats
- ☐ Be cautious walking on ice, especially in early or late winter or during heavy snow cover. If aeration equipment is in operation during winter, designate open water areas with a barricade.
- ☐ Utilize government agencies and private professional consultants for service information about the aquatic environment.
- ☐ Organize a Lake Property Owner's group and formulate a water management plan.
- ☐ Use common sense.

PROFESSIONAL LAKE & POND MANAGEMENT SERVICES

In many areas of the country, professional help is available to assist with lake and pond problems. This assistance is sometimes needed, at least initially, to plan and implement a successful water management program. Professional lake and pond management firms can provide services and/or information on the following:

Chemical Application - Professionals will examine the site and determine the type and extent of vegetation problems. They work closely with government agency personnel and chemical manufacturers to remain up-to-date on regulations and current technology. This information is passed along to their accounts. They will obtain permits (where necessary), apply the chemical and provide follow-up. Professionals are licensed and insured to perform this type of work.

Fish Management - Services may include fish stocking, population studies and rough fish eradication. Assessments may be available utilizing electro-shocking equipment or net surveys to determine the composition and health of the existing population. Application of fish toxicants may be implemented to get rid of unbalanced or undesirable populations and followed up with a prescribed stocking program to improve fishing.

Aeration Equipment Installation - Services may include assessment of dissolved oxygen concentrations and determination of aeration needs. Proper sizing and placement of these systems is required to prevent fish kills, promote healthy fish populations and improve water quality.

Water Quality Analysis - Water sampling and laboratory services may be available through professionals to assess water quality. Identification of existing problems, finding their causes and recommending protection or rehabilitation techniques are the objectives of these studies. Periodic monitoring may be necessary to determine whether water is safe for swimming, susceptible to fish kills, or receiving high levels of pollutants and nutrients. Existing background water quality data must be compiled to determine whether conditions are improving or degrading in the future. These same firms may also be able to assess the safety of drinking water supplies in the area.

Habitat Manipulation - These services may include dredging, use of bottom barriers, application of dyes such as **Aquashade**, deactivation of nutrients or drawdown to improve the environment.

Environmental Studies - Examination of watershed areas for sources of erosion, nutrient loading or pollution are services available from many of these trained professionals. They will work with their customers toward solving problems once they are identified.

Through an integrated approach of studies, protective measures and rehabilitation techniques, professional water management firms can provide short-term improvement to restore recreational activities plus lead the way toward more permanent remedial action.

APPENDIXES

A. PRODUCT INFORMATION SUMMARIES

The following descriptions are for products included in the recommended, maintenance and alternative control methods provided in this book. Always check product labels and literature for complete information before applying.

Navigate granular and **2,4-D Ester** liquid (2,4-dichlorophenoxyacetic acid) manufactured by Rhone-Poulenc Ag Company, Applied Biochemists and various manufacturers (liquid) respectively:

Granular and liquid herbicides containing 2,4-D. Systemic action mainly against dicot ("broad-leaf") weeds, thus providing somewhat selective control. Absorption mainly through leaves, accumulates in meristematic (growth) tissues and causes abnormal growth responses which eventually kill the plant. Liquid used mainly for foliar applications to emergent and floating-leafed plants or large areas of certain submerged species. Control obtained in 2 to 3 weeks following application. Biodegrades within 1 to 4 weeks following application. Treat only actively growing plants, usually before flowering or seed formation.

Aquashade liquid manufactured by Applied Biochemists:

Liquid aquatic dye consisting of a blend of blue and yellow dyes specially designed to screen or shade portions of the sunlight spectrum (red-orange and blue-violet) required by underwater aquatic plant and algae growth. This action effectively inhibits photosynthesis in young, bottom growth and may prevent development altogether if applied early enough in the season. Primarily effective at depths of two feet or greater. Inhibition of Planktonic (suspended) algal blooms has also been proven. Desirable, floating leafed plants are unaffected if they have already surfaced and concentrated product does not contact leaves directly. Is only “colorant” product of its kind that is registered by the U.S. Environmental Protection Agency for aquatic plant growth control. At use dilution, will not stain bathing suits, fountain surfaces or other water features. It is oxidized by chlorine, so some loss of color may be expected in chlorinated water systems. Coloration is gradually lost by dilution, photo-degradation and some bio-degradation over time. However, since these factors will vary, additions needed to maintain color concentrations may range from weekly to monthly.

Aquathol K liquid and **Aquathol** granular (dipotassium endothall) manufactured by Cerexagri, Inc.:

Aquatic herbicides containing dipotassium endothall as their active ingredient function as a contact-type, membrane-active herbicide that inhibits protein synthesis. Considered a broad range herbicide on submerged species. Some species, however, can metabolize endothall and, consequently, show resistance. Kills plants in 1 to 2 weeks. For best results, apply when plants are actively growing in water temperatures above 65°F.

Cide-Kick II liquid manufactured by Brewer International.:

Liquid non-ionic spray adjuvant consisting of d,l-limonene, related isomers plus selected emulsifiers. It is a wetting agent, activator and penetrant all in one. It is a low viscosity oil (a by-product of the forest industry) which is compatible with most terrestrial and aquatic herbicides, insecticides and other pesticides. It helps break down the waxy cuticle on the leaf surface and helps penetrate the bud and bark area (of the woody brush) allowing a more effective uptake of the herbicide.

Clearigate liquid (chelated copper) manufactured by Applied Biochemists:

A chelated copper algaecide/herbicide formulation containing an emulsified surfactant/penetrant for highly effective control of course (thick cell-walled) filamentous algae, mucilaginous (colonial) planktonic algae, Chara and a variety of emergent, floating and submerged aquatic plants. Cellular action through inhibition of photosynthesis. Compatible in wide range of water qualities (fresh, brackish and saltwater). Will not precipitate out of solution in hard water. No water use restrictions following application. Control obtained in 1 to 3 days. Chelating agent biodegrades. Residual copper can remain in solution up to several weeks for extended control. For optimum results, use when water temperatures are above 60°F. Compatible in tank mix combinations with several aquatic herbicides providing enhanced effectiveness.

Cutrine-Plus liquid and **Cutrine-Plus Granular** (chelated copper) both manufactured by Applied Biochemists:

A chelated copper algaecide produced via a patented formulation process wherein copper carbonate is solubilized and chelated (locked-in) with both monoethanolamine and triethanolamine. Product is more stable and far less corrosive than formulations containing copper sulfate or copper hydroxide combined with a single chelating agent. Liquid also has herbicidal properties on aquatic plants such as Hydrilla. Broad-spectrum control of algae. Systemic action through inhibition of photosynthesis. Compatible in wide range of water qualities (fresh, brackish and saltwater). Will not precipitate out of solution in hard water. No water use restrictions following application. Control obtained in 3 to 7 days. Chelating agent biodegrades. Residual copper can remain in solution up to several weeks for extended control. For optimum results, use when water temperatures are above 60°F. Compatible in tank mix combinations with several aquatic herbicides that provides enhanced effectiveness.

Hydrothol 191 liquid and granular (endothall amine) manufactured by Cerexagri, Inc.:

Aquatic herbicide/algaecide containing amine formulation of endothall as active ingredient. Functions similar to Aquathol K in killing plants, biodegradation, etc. **Can be toxic to fish at recommended use rates.** Treat in narrow strips and avoid trapping fish within treatment areas.

Reward and **Weedtrine D** (diquat) manufactured by Syngenta Crop Protection and Applied Biochemists respectively:

Liquid herbicides containing diquat dibromide contact-type action, absorbed through plant cuticle, destroys cellular membranes. Broad range control of submerged, floating and emergent species. Wilting and desiccation of plant parts occurs within days and death within 2 weeks. Chemical disappears from the environment by photo-degradation and absorption onto silt and clay particles. **Do NOT use in muddy water or on silt-covered plants** as chemical will be deactivated and poor control will result. Apply to actively growing plants when water temperatures are above 60°F.

Shore-Klear (glyphosate) manufactured by Applied Biochemists

A liquid herbicide containing glyphosate as its active ingredient. Controls a wide range of emergent-type plants growing in and around aquatic sites. Systemic action and complete translocation leading to reduced protein synthesis, cessation of growth, cellular disruption and death. Uptake within 6 hours after treatment, with wilting and yellowing of plants occurring 2 to 7 days after treatment. Best time to treat is when plants are matured or as specifically recommended on label. Biodegradable in water and soil within weeks following application.

Fluridone (various liquid or pelletized formulations): manufactured by SePRO Corporation:

Aquatic herbicide formulations containing fluridone as their active ingredient. Relatively slow systemic action inhibits carotenoid synthesis in vascular plants resulting in photo-degradation of chlorophyll. Typical early symptom is loss of green coloration from plants (chlorosis). Knockdown and control of plants may take 30 to 90 days following application. Non-persistent in the environment, most loss through photo-degradation. Apply prior to initiation of weed growth or when weeds begin actively growing. Not recommended for spot treatments or where dilution or water movement will not allow long enough contact time. Acceptable cost-effectiveness from use of this relatively expensive product is based upon obtaining control for more than 1 season, which **may** occur from a single application.

B. GENERAL RESTRICTIONS ON USE OF TREATED WATER (Number of Days)

(Always refer to current product label for specific requirements)

COMMON NAME (FORMULATION)	CHEMICAL NAME	AMOUNT OF ACTIVE INGREDIENT	HUMAN: DRINKING	HUMAN: SWIMMING	HUMAN: FISH CONSUMPTION	ANIMAL DRINKING	IRRIGATION: TURF	IRRIGATION: FORAGE	IRRIGATION: FOOD CROP
2,4-D (liquid)	2,4-dichlorophenoxyacetic acid (IOE)	3.8 lbs. per gal.	*	*	*	*	*	*	*
Aquashade/Aquashadow	acid blue dye #9 & acid yellow dye #23	27%/2%	*	0	0	0	0	0	0
Aquathol (granular)	dipotassium salt of endothall	10.10%	7	0	3	7	7	7	7
Aquathol K (liquid)	dipotassium salt of endothall	4.23 lbs. per gal.	7-25	0	3	7-25	0****	7-25	7-25
Clearigate (liquid)	emulsified copper ethanolamines formulation	3.83%	0	0	0	0	0	0	0
Cutrine-Plus (granular)	copper alkanolamine complexes	3.70%	0	0	0	0	0	0	0
Cutrine-Plus (liquid)	copper alkanolamine complexes	9.00%	0	0	0	0	0	0	0
Fluridone (liquid)	fluridone	41.70%	**	0	0	0	30***	30***	30***
Fluridone (pellet)	fluridone	5.00%	**	0	0	0	30***	30***	30***
Hydrothol 191 (granular)	mono (N,N-dimethylalkylamine) salt of endothall	11.20%	7-25	0	3	7-25	7-25	7-25	7-25
Hydrothol 191 (liquid)	mono (N,N-dimethylalkylamine) salt of endothall	53.00%	7-25	0	3	7-25	7-25	7-25	7-25
Navigate	2,4-dichlorophenoxyacetic acid (BEE)	27.60%	*	0	0	0	*	*	*
Reward (liquid)	diquat dibromide	2 lb. Diquat cation per gal.	3	0	0	1	3	3	5
Rodeo (liquid)	isopropylamine salt of glyphosate	53.50%	**	0	0	0	0	0	0
Weedtrine® D (liquid)	diquat dibromide	8.53%	5	1	0	5	5	5	5

* In cases where restrictions are not given in above chart, consult your State Conservation Commission or Fish & Game Department for specific restrictions. Chemical manufacturers and manufacturer's representatives can also supply you with specific recommendations based upon water usage.

** See label for distance allowed from potable water intake.

*** Restrictions suggested by manufacturer to limit damage to irrigated plants.

**** For bent grass only.

NOTE: Waiting period ranges given for endothall products (7-25 days) are dependent upon dosages used. See labels for accurate determinations.

NOTICE: Copper sulfate is not included in this chart nor is it recommended in this book due to problems with copper build-up in sediments and toxicity to aquatic organisms (see pages 5, 6, 30 & 32).

C. METRIC/ENGLISH MEASUREMENT CONVERSIONS

The following conversions and data have been prepared to assist with calculation of treatment area size and product dosages into metric units.

VOLUME, WEIGHT & DISTANCE MEASUREMENTS

English to Metric			Metric to English		
1 gallon	=	3.785 litres	1 liter	=	0.264 gallons
1 fluid ounce	=	29.57 milliliters	1 milliter	=	0.034 fluid ounce
1 pound	=	453.6 grams	1 gram	=	0.0022 pounds
1 pound	=	0.454 kilograms	1 kilogram	=	2.20 pounds
1 ounce (wt.)	=	28.35 grams	1 gram	=	0.035 ounce (wt.)
1 foot	=	0.305 meters	1 meter	=	3.28 feet
1 acre 43,560 sq. ft	=	0.405 hectares (4,052 sq. meters)	1 hectare	=	2.47 acres
1 acre-foot (43,560 cu. ft)	=	0.123 hectare-meters	1 hectare-meter	=	8.1 acre-feet

VOLUME & WEIGHT Relationships of Water
1 gallon weight 8.345 pounds
1 liter weight 1000 grams
1 metric ton = 1,000 liters = 1 m³ = 264 gallons
1 cubic foot contains 7.48 gallons
1 acre-foot contains 325,869 gallons
1 acre-foot weight 1,234 metric tons
1 hectare-meter contains 10,000,000 liters
1 hectare-meter weighs 10,000 metric tons

PARTS PER MILLION (PPM) Calculations

1 PPM =

- 1 milligram/liter
- 1 milligram/kilogram
- 1 gram/metric ton
- 2.72 pounds/acre-foot
- 3.78 milligrams/gallon
- 8.34 pounds/million gallons

D. QUICK REFERENCE ACREAGE CALCULATION CHART

AREA (in surface acres)

WIDTH (in feet)	LENGTH (in feet) 100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
100	0.23	0.34	0.46	0.57	0.69	0.80	0.92	1.03	1.15	1.26	1.38	1.49	1.61	1.72	1.84	1.95	2.07	2.18	2.30
150	0.34	0.52	0.69	0.86	1.03	1.21	1.38	1.55	1.72	1.89	2.07	2.24	2.41	2.58	2.75	2.93	3.10	3.27	3.44
200	0.46	0.69	0.92	1.15	1.38	1.61	1.84	2.07	2.30	2.53	2.75	2.98	3.21	3.44	3.67	3.90	4.13	4.36	4.59
250	0.57	0.86	1.15	1.43	1.72	2.01	2.30	2.58	2.87	3.16	3.44	3.73	4.02	4.30	4.59	4.88	5.17	5.45	5.74
300	0.69	1.03	1.38	1.72	2.07	2.41	2.75	3.10	3.44	3.79	4.13	4.48	4.82	5.17	5.51	5.85	6.20	6.54	6.89
350	0.80	1.21	1.61	2.01	2.41	2.81	3.21	3.62	4.02	4.42	4.82	5.22	5.62	6.03	6.43	6.83	7.23	7.63	8.03
400	0.92	1.38	1.84	2.30	2.75	3.21	3.67	4.13	4.59	5.05	5.51	5.97	6.43	6.89	7.35	7.81	8.26	8.72	9.18
450	1.03	1.55	2.07	2.58	3.10	3.62	4.13	4.65	5.17	5.68	6.20	6.71	7.23	7.75	8.26	8.78	9.30	9.81	10.3
500	1.15	1.72	2.30	2.87	3.44	4.02	4.59	5.17	5.74	6.31	6.89	7.46	8.03	8.61	9.18	9.76	10.3	10.9	11.5
550	1.26	1.89	2.53	3.16	3.79	4.42	5.05	5.68	6.31	6.94	7.58	8.21	8.84	9.47	10.1	10.7	11.4	12.0	12.6
600	1.38	2.07	2.75	3.44	4.13	4.82	5.51	6.20	6.89	7.58	8.26	8.95	9.64	10.3	11.0	11.7	12.4	13.1	13.8
650	1.49	2.24	2.98	3.73	4.48	5.22	5.97	6.71	7.46	8.21	8.95	9.70	10.4	11.2	11.9	12.7	13.4	14.2	14.9
700	1.61	2.41	3.21	4.02	4.82	5.62	6.43	7.23	8.03	8.84	9.64	10.4	11.2	12.1	12.9	13.7	14.5	15.3	16.1
750	1.72	2.58	3.44	4.30	5.17	6.03	6.89	7.75	8.61	9.47	10.3	11.2	12.1	12.9	13.8	14.6	15.5	16.4	17.2
800	1.84	2.75	3.67	4.59	5.51	6.43	7.35	8.26	9.18	10.1	11.0	11.9	12.9	13.8	14.7	15.6	16.5	17.4	18.4
850	1.95	2.93	3.90	4.88	5.85	6.83	7.81	8.78	9.76	10.7	11.7	12.7	13.7	14.6	15.6	16.6	17.6	18.5	19.5
900	2.07	3.10	4.13	5.17	6.20	7.23	8.26	9.30	10.3	11.4	12.4	13.4	14.5	15.5	16.5	17.6	18.6	19.6	20.7
950	2.18	3.27	4.36	5.45	6.54	7.63	8.72	9.81	10.9	12.0	13.1	14.2	15.3	16.4	17.4	18.5	19.6	20.7	21.8
1000	2.30	3.44	4.59	5.74	6.89	8.03	9.18	10.3	11.5	12.6	13.8	14.9	16.1	17.2	18.4	19.5	20.7	21.8	23.0

DOSAGE CALCULATIONS

The following charts are useful in calculating specific amounts of chemical required to treat a known amount of area. Use them as follows:

1. If dosage is given in gallons per acre-foot, use **Chart E** to determine gallons per surface acre required based upon average depth.
2. Take dosage per surface acre and refer to the appropriate column in **Chart F** to determine amount of chemical and minimum dilution water required per unit area.

E. GALLONS REQUIRED PER SURFACE ACRE BASED UPON AVERAGE DEPTH

(Based upon the recommended dosage in
gallons per acre-foot and the average depth of the area to be treated,
use this chart to determine gallons to apply per surface acre.)

DOSAGE RATE IN GALLONS PER ACRE-FOOT	AVERAGE DEPTH IN FEET					
	1	2	3	4	5	6
0.3	0.3	0.6	0.9	1.2	1.5	1.8
0.4	0.4	0.8	1.2	1.6	2.0	2.4
0.5	0.5	1.0	1.5	2.0	2.5	3.0
0.6	0.6	1.2	1.8	2.4	3.0	3.6
0.7	0.7	1.4	2.1	2.8	3.5	4.2
0.8	0.8	1.6	2.4	3.2	4.0	4.8
0.9	0.9	1.8	2.7	3.6	4.5	5.4
1.0	1.0	2.0	3.0	4.0	5.0	6.0
2.0	2.0	4.0	6.0	8.0	10.0	12.0
3.0	3.0	6.0	9.0	12.0	15.0	18.0

F. DOSAGE AND MINIMUM DILUTION BASED UPON GALLONS TO APPLY PER SURFACE ACRE

Based upon gallons to apply per surface acre [determined from Chart E or product label], use the chart below to determine amount of chemical and minimum amount of dilution water required per specified area.

RECOMMENDED GALLONS PER SURFACE ACRE	AMOUNT OF CHEMICAL (C) AND MINIMUM AMOUNT OF DILUTION WATER (W) TO USE PER UNIT AREA					
	1 Acre (43,560 sq. ft.)	2/3 Acre (29,040 sq. ft.)	1/2 Acre (21,780 sq. ft.)	1/3 Acre (14,520 sq. ft.)	1/4 Acre (10,890 sq. ft.)	1/5 Acre (8,712 sq. ft.)
0.3 (38 oz.)	38 oz. C 3 gal. W	26 oz. C 2 gal. W	19 oz. C 1.5 gal. W	13 oz. C 1 gal. W	10 oz. C 3 qts. W	8 oz. C 2 qts. W
0.4 (51 oz.)	51 oz. C 3.5 gal. W	34 oz C 2.5 ga. W	26 oz. C 2 gal. W	17 oz. C 1.5 gal. W	13 oz. C 1 gal. W	10 oz. C 3 qts. W
0.5 (64 oz.)	64 oz. C 4.5 gal. W	43 oz C 3 gal. W	32 oz. C 2.5 gal W	21 oz. C 1.5 gal. W	16 oz. C 5 qts. W	13 oz. C 1 gal. W
0.6 (77 oz.)	77 oz. C 5.5 gal. W	51 oz C 3.5 ga. W	39 oz. C 3 gal. W	26 oz. C 2 gal. W	19 oz. C 1.5 gal. W	15 oz. C 1 gal. W
0.7 (90 oz.)	90 oz. C 6.5 gal. W	60 oz C 4.5 ga. W	45 oz. C 3.5 gal. W	30 oz. C 2.5 gal. W	23 oz. C 2 gal. W	18 oz. C 1.5 gal. W
0.8 (102 oz.)	102 oz. C 7.5 gal. W	68 oz C 5 gal. W	51 oz. C 3.5 gal. W	34 oz. C 2.5 gal. W	26 oz. C 2 gal. W	20 oz. C 1.5 gal. W
0.9 (115 oz.)	115 oz. C 8 gal. W	77 oz C 5.5 ga. W	58 oz. C 4 gal. W	38 oz. C 3 gal. W	29 oz. C 2 gal. W	23 oz. C 2 gal. W
1.0	1 gal. C 9 gal. W	85 oz C 6 gal. W	64 oz. C 4.5 gal. W	43 oz. C 3 gal. W	32 oz. C 2.5 gal. W	26 oz. C 2 gal. W
2.0	2 gal. C 10 gal. W	1.3 gal. C 12 gal. W	1 gal. C 9 gal. W	85 oz. C 6 gal. W	64 oz. C 4.5 gal. W	51 oz. C 3.5 gal. W
3.0	3 gal. C 27 gal. W	2 gal. C 18 gal. W	1.5 gal. C 14 gal. W	1 gal. C 9 gal. W	96 oz. C 7 gal. W	77 oz. C 6 gal. W
4.0	4 gal. C 36 gal. W	2.6 gal. C 24 gal. W	2 gal. C 18 gal. W	1.3 gal. C 12 gal. W	1 gal. C 9 gal. W	102 oz. C 7.5 gal. W
5.0	5 gal. C 45 gal. W	3.3 gal. C 30 gal. W	2.5 gal. C 23 gal. W	1.7 gal. C 15 gal. W	1.3 gal. C 12 gal. W	1 gal. C 9 gal. W

G. IRRIGATION CONVEYANCE SYSTEM TREATMENT GUIDELINES

A limited number of products are registered or allowed for use in flowing water systems, particularly within agricultural irrigation waters. Acrolein and xylene, available on a restricted basis, pose severe environmental and safety concerns. A number of products have been proven impractical since they impose extended water use restrictions or act too slowly in killing target aquatic vegetation. The ideal product(s) must pose limited risk to the applicator and the environment, have no restrictions on use of the water for irrigation and quickly control the vegetation present.

Cutrine-Plus and Clearigate meet these criteria as an effective algaecide and algaecide/aquatic herbicide, respectively, for use in irrigation conveyance systems. These chemical technologies from Applied Biochemists are proven cost-effective alternatives to copper sulfate, xylene and acrolein.

Both products contain chelated copper as their active ingredients. Unlike copper sulfate, the copper remains in solution under a wide variety of water quality conditions. This extended contact time of the soluble copper provides more complete and extended control of algae. In the case of Clearigate, a patented emulsification/adjuvant system within the formulation makes the copper readily available for uptake by submersed and floating aquatic plants. This results in a rapid weakening and death of these vascular plants. Extended downstream control plus reduced application frequency can be expected from both formulations, as compared to use of old technologies. Algae typically dies and decays within 24 – 48 hours post-treatment. Rooted plants go through a process of knockdown, decay and disappearance during a 2 – 10 day period.

Both products are registered with the U. S. Environmental Protection Agency and with the State Departments of Agriculture. International registration and use is prevalent throughout the world. The labeled use for both products allows up to 1.0 ppm copper in the treated water following product application. This is consistent with the Federal U.S. copper tolerance level of 1.0 ppm copper established for drinking water (CFR Title 21, Part 193.90) and the exemption from the requirement of a tolerance in eggs, fish, meat, milk, irrigated crops and shellfish (CFR Title 40, Part 180.1021).

Cutrine-Plus and Clearigate are virtually non-corrosive to application equipment. They can be applied through a variety of delivery systems. Neither product imposes water use restrictions for drinking, swimming, fishing, irrigating or domestic use during or following treatment.

Effective treatment of flowing water systems is dependent upon: 1) copper concentration, 2) contact time, 3) degree of infestation, 4) type of growth present, 5) water conditions, and 6) weather conditions (e.g. sunlight).

Experience has proven that control can be achieved in flowing water by treating with higher dosages (up to 1 ppm copper) for shorter contact periods (6 hours or less) or lower dosages (down to 0.2 ppm copper) for longer contact periods (24 hours or more). Therefore dosage and duration selections must be made to provide a suitable treatment. Dosages less than the maximum rate of 1 qt/cfs/hr for Cutrine-Plus or 2.8 qt/cfs/hr for Clearigate can be used when extended contact time is maintained due to slower water turnover rates. Use of lower dosage rates should only be considered when water temperatures are above 60°F, optimum weather conditions prevail and the vegetation infestation is light to moderate.

Frequency of treatments required will vary from system to system depending upon weather, length of season, water quality, type of growth present and bank/bottom construction. An effective treatment should maintain control for 3 – 6 weeks. Initial treatment should be made at the first visible signs of growth or when flow restriction first becomes apparent. Ideally water temperatures should be at or above 60°F.

Drippers or metering pumps are utilized to properly feed product into the flowing water at a rate proportionate to water flow such that chemical concentration remains constant for the duration of treatment. Drippers are simple, valve-regulated pipes, which provide a constant head pressure in the chemical tank via a vent tube. Output is depended upon pipe size. Twelve-volt metering pumps provide a simple method of adjusting output rates. They can be equipped with flow devices, which automatically adjust chemical output to stream flow. Specifications for this equipment are available though Applied Biochemists,

The following Drip/Metering System Calculation, Calibration & Worksheet instructions are based upon using labeled dosage rates for Cutrine-Plus and Clearigate. Any reduction in dosage rate should take into consideration the previously mentioned factors. Good judgement, experimentation and experience will assist in optimizing a cost-effective treatment program.

DRIP SYSTEM CALCULATION, CALIBRATION & WORKSHEET

The following can be used as a standard step-by-step procedure for setting up drip/metering systems along a canal to ensure sufficient contact time at the labeled maximum dosage rate. (NOTE: "A" entries are examples based on the data below and "B" entries are for your calculations.)

Example:	Canal Length: 10 miles x 5,280 ft = 52,800 ft	Average Width:	10 ft
	Fow Rate: 120 cfs	Average Depth:	4 ft
Your Data:	Canal Length: ___ miles x 5,280 ft = ______ ft	Average Width:	_____ ft
	Flow Rate: ___ cfs	Average Depth:	_____ ft

Step #1 – Determine Flow Rate - Prior to treatment it is important to accurately determine water flow rates. In the absence of weirs, orifices or similar devices, which provide accurate water flow measurements, volume of flow may be estimated via the following formula:

Average Width (ft) x Average Depth (ft) x Velocity* (ft/sec) x 0.9 = Cubic Feet per Second (cfs)

*Velocity is the time it takes a floating object to travel a given distance. Dividing the distance traveled (ft) by the time (seconds) will yield velocity (ft/sec). Repeat measurements at least 3 times at the intended application site and use the average of these measurements.

Step #2 - Calculate Canal Volume - Calculate canal volume in cubic feet based upon water levels at the time of treatment by using the following formula:

Canal Length (ft) x Average Width (ft) x Average Depth (ft) = Cubic feet of water (^{3})

A. 52,800 ft x 10 ft x 4 ft = 2,112,000 ft^3

B. _____ ft x __ ft x _ ft = ________ ft^3

Step #3 - Calculate Turnover Time - Calculate the amount of time it takes for the water in the canal to be replaced by new water based upon water flow rate at the time of treatment by using the following formula:

[Canal Volume (ft^3) ÷ Flow Rate (cfs)] ÷ 3,600 = Turnover Time in Hours

A. [2,112,000 (ft^3) ÷ 120 (cfs)] ÷ 3,600 = 4.9 hr

B. [________ (ft^3) ÷ ____ (cfs)] ÷ 3,600 = ___ hr

Step #4 - Calculate Total Cutrine-Plus or Clearigate Requirements – Select a dosage rate from the chart on the Clearigate label. For Cutrine-Plus, use the 1 qt./CFS/hr rate.

[Label Dosage Rate (qt/cfs/hr) x Flow Rate (cfs) x Turnover Time (hr)*] ÷ 4 =

Chemical required (gal)

A. [1 qt/cfs/hr x 120 cfs x 4.9 hr] ÷ 4 = 147 gal

B. Clearigate: [___qt/cfs/hr x ___ cfs x __ hr*****] ÷ 4 = ___ gal

Cutrine-Plus: [1 qt/cfs/hr x ___ cfs x __ hr*****] ÷ 4 = ___ gal

***NOTE:** If Turnover Time is less than 3 hours, substitute 3 hours into this calculation.

Step #5 - Number of Drip/Metering Sites - Use the table below to determine the number of drip sites required based upon Turnover Time (hrs):

Turnover Time (hr)	Number of Drip Sites
Less than 4.5	1
4.6 to 7.5	2
7.6 to 10.5	3
10.6 to 13.5	4
13.6 to 16.5	5

For every additional 3 hours of Turnover Time, add 1 additional drip/metering site.

Step #6 - Distance Between Drip/Metering Sites - Determine the distance required between drip/metering sites using the following formula:

Canal Length (ft) ÷ Number of Drip/Metering Sites = Distance Between Drip Sites (ft)

A. 52,800 ft ÷ 2 sites** = 26,400 ft between drip sites

**Based upon the example Turnover Time of 4.9 hrs calculated in Step #3, the table above indicates that 2 drip systems are required.

B. _____ ft ÷ ___ sites = ______ ft between drip sites***

***Place the first treatment site at the head of the system. Measure the calculated number of feet downstream for the next treatment site, then from that point to the next site and continuing downstream until the required number of treatment sites are in place.

Step #7 - Cutrine-Plus Required for Drip/Metering Site - Calculate as follows:

Total Chemical Required (gal) ÷ # of drip sites = Chemical per site (gal) x 4 = Chemical per site (qt)

A. 147 total gal ÷ 2 drip sites = 73.5 gal per site x 4 = 294 qt per site

B. ___ total gal ÷ _ # of sites = ____ gal per site x 4 = ___ qt per site

Step #8 - Drip Duration Per Site – Calculate drip/metering duration per site by using the following formula:

Chemical Required per site (qt) ÷ [Dosage Rate (qt/cfs/hr x flow rate (cfs))] = Drip/Metering Duration (hrs) per site

A. 294 qt per site ÷ [1 qt/cfs/hr x 120 cfs] = 2.45 hr per site

B. ___ qt per site ÷ [___ qt/cfs/hr x ___ cfs] = ____ hr per site

Step #9 - Drip Rate Conversion & Calibration - Calculate drip/metering rate into ounces (oz) or milliliters (ml) per minute:

For Ounces: Flow Rate (cfs) x Drip Rate (1 qt/cfs/hr) x 0.534 = Drip Rate (oz/min)

For Millimeters: Drip Rate (oz per min) x 29.57 = Drip Rate (ml/min)

A. 120 cfs x 1 qt/cfs/hr x 0.534 = 64 oz/min x 29.57 = 1,892 ml/min

B. ___ cfs x ___qt/cfs/hr x 0.534 = ____ oz/min x 29.57 = _____ ml/min

Conclusion & Explanation - Based upon the example used, this canal would be treated with 2 drip systems 26,400 ft (5 miles) apart. Each would be supplied with 73.5 gal of Chemical to be applied simultaneously at the rate of 64 oz per minute (1,892 ml/min). Treatment would take 2.45 hr. Suitable contact time is ensured and copper levels within any section of the canal should not exceed labeled rates.

Dosage Rates vs. Copper Concentration Relationships****				
Copper Concentration In Treated Water	**Dosage Rate**			
	Cutrine-Plus		**Clearigate**	
ppm	**oz/cfs**	**ml/cfs**	**oz/cfs**	**L/cfs**
1.0	32	946	90	2.66
0.9	29	852	81	2.40
0.8	26	757	72	2.13
0.7	22	662	63	1.86
0.6	19	568	54	1.60
0.5	16	473	45	1.33
0.4	13	378	37	1.09

******NOTE**: The above reduced dosage rates are provided for consideration to use in slower moving systems where extended retention times exist vegetation infestation is low and optimum treatment conditions exist.

Calibrate drip system, metering pump or similar dosage device to establish output rate determined in Step No. 9. This can be done using a watch with a second hand and a calibrated measuring cup, graduated cylinder or similar vessel.

If possible, calibrate all drip/metering devices prior to actual treatment. Turn them on as simultaneously as possible, beginning with the device furthest upstream.

Begin with only the amount of product required at each site or record your start-up time and shut down drip/metering duration time period determined in Step No. 8.

Remove containers from application sites following treatment. Triple rinse application equipment. Dispose of empty containers in accordance with container disposal instructions on label. Partially used containers should be resealed with original closures and stored in accordance with storage instruction on this label.

Always read and follow all label directions and precautions on the product label.

For further technical assistance, contact your regional Applied Biochemists Technical Sales Representative or call their Customer Service Department toll-free at 1-800-558-5106.

H. Notes

Lake/Pond Diary

Date	Action Taken

Lake/Pond Diary

Date	Action Taken

Lake/Pond Diary

Date	Action Taken

Lake/Pond Diary

Date	Action Taken

GLOSSARY

acclimated: to become accustomed to. In the case of fish stocking, water temperature of the fish stock water and the lake or pond should be roughly the same before releasing fish.

adjuvant: a substance added to a spray solution to assist in the performance of the product. Usually functions in helping chemical stick to, wet, or penetrate the plant surface.

aerobic: in the presence of oxygen.

algaecide: a substance (chemical) which kills algae.

anaerobic: devoid of oxygen.

aquaculture: the cultivation of marine or freshwater organisms under controlled environmental conditions.

berm: a raised edge or shoulder running along the edge of a pond to prevent direct surface run-off from entering.

biodegradation: the decomposition or breakdown of a substance into its basic chemical components through the action of bacteria and other microorganisms.

BOD (Biochemical Oxygen Demand): a standard laboratory test (usually done on wastewater) to determine the amount of oxygen required to decompose organic materials and oxidize inorganic substances within a water sample incubated at 20°C over a set period of time.

chelated: chemical terminology used to describe a specific type of compound in which a metal is bound or held by two or more other chemical substances. The chelated metal will have unique properties unlike the metal in its uncombined form.

contact herbicide: a product which kills weeds by destroying the surface of plant foliage causing them to wilt, discolor or dry up.

desiccation: to lose moisture or dry up.

de-stratification: the loss of layering or, as in the case of water, the mixing of waters at various temperatures and depths within the water column until an average, uniform temperature is reached. De-stratification occurs naturally in spring and fall as waters warm and cool, respectively, or can be induced with the use of aeration equipment.

effluent: water being discharged or flowing out such as at an outflow. Often refers to water leaving a sewage treatment pond or facility.

eutrophic/eutrophication: being nutrient enriched or the process of nutrient enrichment of a body of water. A category within a lake or pond water quality classification system.

exotic: referring to something which is not native to an area. Plants or animals which have been introduced from other geographical regions, often by man.

formulation: the form in which a chemical is available for use (e.g. liquid, granular, powder, etc.)

herbicide: a substance (chemical) which kills vascular plants. Vascular plants are those which have internal systems for transporting nutrients, water and gases.

herbivore: an animal which consumes plants.

invertebrate: animals without backbones (e.g. insects, crustaceans, mollusks, etc.).

littoral zone: general area of the bottom of a body of water where sunlight penetrates sufficiently to support aquatic plant growth. Typically shoreline areas, areas surrounding islands or similar features.

microbial bio-augmentation: the addition of microorganisms (microscopic in size) and/or enzymes to add a component or complement an existing component of an ecosystem.

midrib: the central "vein" of a leaf, usually distinguished by being sturdier and more pronounced than the rest of the leaf.

non-ionic surfactant: a soap-like additive used in a spray solution to improve its sticking and wetting properties when applied to plant foliage. Non-ionic refers to solution without any electrical charge.

non-target organism: a plant or animal not intended to be harmed or killed by the application of a chemical.

pathogen: a disease-producing organism.

petiole: the stalk connecting a leaf to the stem.

photosynthesis: the process by which plants convert carbon dioxide and water into sugars (carbohydrates) using sunlight as the energy source.

precipitate: 1. the chemical process in which a substance in solution reacts with other chemical constituents making it insoluble so that it falls out of solution. 2. the insoluble substance formed by such a reaction.

rhizome: a root-like underground stem (usually growing horizontally) capable of producing plant shoots from the top and roots from the bottom.

rootstock: a root containing buds. Also used synonymously with rhizome.

spike: an elongated unbranched stalk containing close rows of flowers (or seeds).

summerkill: a die-off of fish occurring during warm weather caused by oxygen depletion. Results from decomposition or respiration of aquatic plants and the inability of warm water to retain high enough concentrations of dissolved oxygen.

systemic: refers to a chemical which is taken (absorbed) into a plant disrupting one or more internal biological processes such as photosynthesis, growth, flower production, etc.

thermal stratification: the layering of water within a lake or pond resulting from water at different temperatures having different densities. Water is heaviest at 39°F (4°C), therefore, warmer or colder water will be found above this strata.

tuber: a fleshy outgrowth of an underground shoot used for storage of carbohydrates and capable of producing new growth (a potato is an example of a tuber).

watershed: the drainage area feeding into a body of water. This would include all upland areas, rivers, streams, springs and groundwater contributing to a surface water supply.

winterkill: a fish die-off occurring during ice cover caused by oxygen depletion. Results from the decomposition of plants and organic materials using up available oxygen and the inability of plants to photosynthesize (produce oxygen) under snow-covered ice.

zooplankton: tiny floating or drifting animals found within the water column. Some of these may be microscopic (not visible to the naked eye). Many feed upon planktonic algae or particulates in the water and, in turn, are fed upon by aquatic insects and fish.

INDEX

CLEAN WATER CONSULTATION

The following data will enable your consultant to evaluate and pinpoint your aquatic nuisance problems and make recommendations for their control. Please fill in as many blanks as you can and be as specific as possible, particularly as to the type of weeds and algae present. Mail this form to your consultant or resource agency per the instructions on the back or call 1-800-558-5106 for assistance.

Your Name: ______________________________ Telephone: (____)________

Address:____

City: _______________________ State: ______ Zip Code: _____________

Name & Location of Lake/Pond____________________________________

____ Size (acres): ____________

Committee Members	Telephone

1. PROBLEMS: Please describe type of weed and algae growth.

____

____

____

2. WATER USES (Check all that apply):

_____ Swimming _____ Boating _____ Fishing _____ Water Supply
Other: ____

Fish Varieties: ____

3. CHARACTERISTICS OF LAKE/POND
Water Temperature (approx.): _______°F Hardness:_______________

4. PRIOR TREATMENT - CHEMICALS USED:

A. Type & Price:____

B. Frequency of Application:_____________________________________

C. Annual Budget for Chemicals:__________________________________

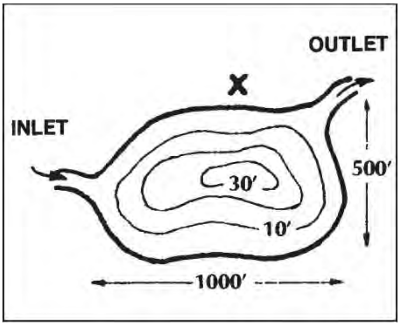
D. Quantities Used:____

E. Name of Applicating Company:_________________________________

Please complete back of form.

SKETCH OF LAKE/POND

SAMPLE SKETCH



CHECK LIST

BE SURE YOUR SKETCH SHOWS:

Scale Used:____________________

Length of Lake/Pond:____________ft.

Width of Lake/Pond:_____________ft.

Depth - Average:________________ft.

Maximum:______________ ft.

SKETCH SHOULD ALSO SHOW:

- Depth Contours
- Inlets
- Springs
- Locations of Growth

YOUR SKETCH

NOTE: Send aquatic weed samples with this form to your consultant or resource agent for identification. Simply pack the weeds or algae in a damp paper towel and seal it in a plastic zipper-type sandwich bag. Call 1-800-558-5106 for assistance.

CONSULTATION

Professional help is available through our worldwide network of distributors and commercial applicators. Contact the company at the bottom of this page (if indicated), call our toll-free number or e-mail us via our web site.

Applied Biochemists, a division of Advantis Technologies, Inc., maintains a staff of trained biologists to provide technical assistance with questions you may have regarding aquatic vegetation problems. Call 1-800-558-5106 (toll-free) or follow the instructions on the CLEAN WATER CONSULTATION FORM (page 127) for additional assistance. Local experts may be available for assistance in your area or arrangements can be made to send someone to your site. **Applied Biochemists'** web site address is **www.appliedbiochemists.com** and our e-mail address is **info@appliedbiochemists.com**.

Marine Biochemists' web site address is **www.marinebiochemists.com** and their e-mail address is **info@marinebiochemists.com**.

Products
and/or
information
available
from: