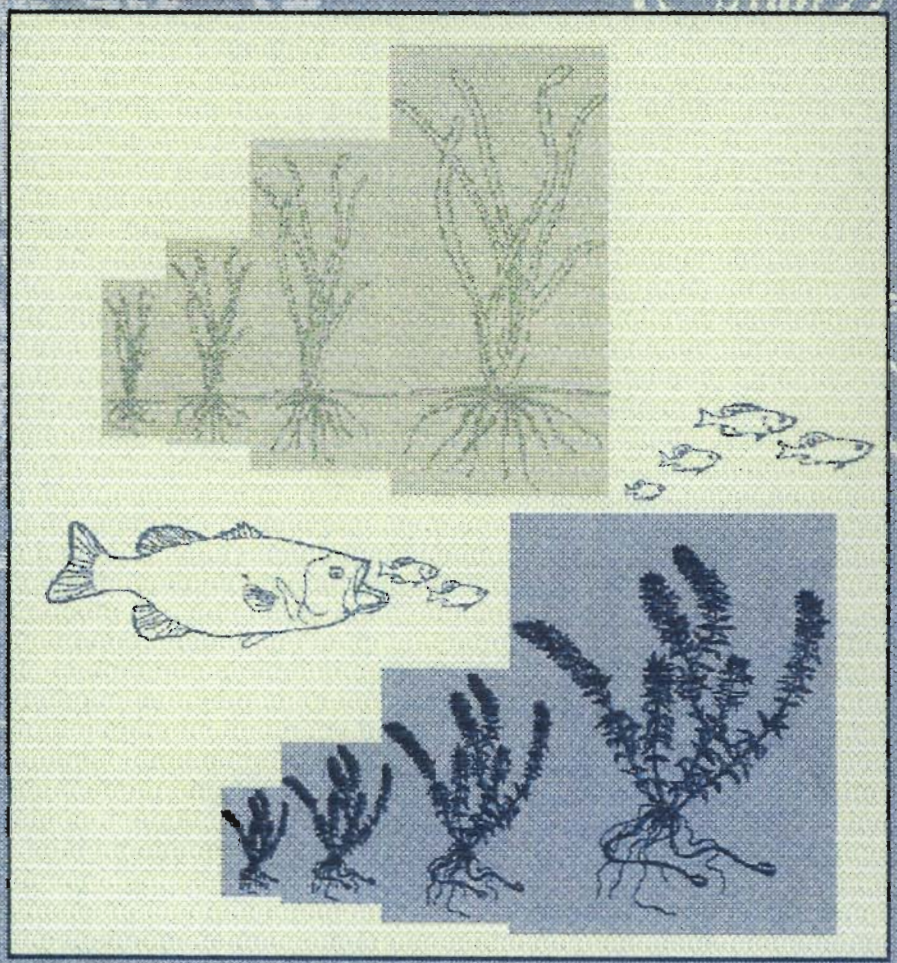
Economic & Environmental Impacts of N. C. Aquatic Weed Infestations



N.C. Department of Environment, Health, and Natural Resources

ECONOMIC AND ENVIRONMENTAL IMPACTS OF N.C. AQUATIC WEED INFESTATIONS

DIVISION OF WATER RESOURCES

DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES

APRIL 1996

EXECUTIVE SUMMARY

The North Carolina General Assembly directed the Division of Water Resources of the Department of Environment, Health, and Natural Resources and the North Carolina Aquatic Weed Council to study aquatic weed infestations in North Carolina. The Division of Water Resources compiled information from state and federal agencies, universities, municipalities, and industry in order to present an accurate account of the threat noxious aquatic weeds pose to state resources. In addition, the Tennessee Valley Authority, Florida, and South Carolina, which have established aquatic weeds programs, were contacted to benefit from their experience.

Exotic plants are those that are introduced to new habitats from their native range. These plants become problems when they spread rapidly in the absence of the natural constraints that exist in their native range. Exotic noxious plants that infest large areas of North Carolina public waters are hydrilla (originally from Asia and Africa), alligatorweed (originally from South America), and Eurasian watermilfoil.

The North Carolina Aquatic Weed Control Program was initiated in 1982. Governor James B. Hunt, Jr. directed the Secretary of the Department of Natural Resources and Community Development (predecessor of the Department of Environment, Health, and Natural Resources) to establish an aquatic weed control program and to assemble an interagency council to oversee aquatic weed control activities. A bill developed by the Aquatic Weed Control Council became the Aquatic Weed Control Act of 1991. This Act defines "noxious aquatic weeds," and authorizes the Secretary of the Department of Environment, Health, and Natural Resources to protect water bodies from infestations of these weeds and to conduct control activities. The Act empowers the Commissioner of Agriculture to regulate the sale, use, culture, collection, transportation, and distribution of noxious aquatic weeds. In 1995, the Aquatic Weed Control Program carried out 46 weed control projects including the large project at Lake Gaston, which received 96 separate treatments.

Hydrilla in several Piedmont reservoirs has been reduced to the level where it no longer causes significant problems, primarily by the use of grass carp. Although hydrilla continues to expand in Lake Gaston, grass carp recently have been introduced to complement herbicide treatments. Integration of chemical and biological control methods should help curb hydrilla spread in Lake Gaston as well as contain and reduce existing populations around the lake. Large expanses of coastal rivers and streams that were once blocked by mats of alligatorweed have been successfully cleared through chemical treatments.

These waterways will remain open to navigation and recreation as long as limited maintenance control continues in these areas.

Control, research, and education are the three key elements of a successful aquatic weed control program. A proactive approach to aquatic weed control includes annual surveys, intensive control efforts for new or large infestations, and follow-up maintenance control. Thorough aquatic plant surveys each year are imperative in the early detection of new noxious weed infestations. Research complements control. Understanding aquatic plant biology and aquatic ecosystems is critical when making decisions about aquatic weed control. The only federal funding source for aquatic plant research has been eliminated at a time when there is a need for more research on hydrilla and on native plants in North Carolina. No effort to combat the spread of hydrilla or alligatorweed will be successful without continued public awareness and cooperation. Information about aquatic weed identification, biology, effects on water bodies, and control methods must be distributed to the public to prevent aquatic weed spread by boating and other human activities.

Early detection and immediate control measures can reduce damages caused by aquatic weeds and lower control costs. The amount of support and personnel required for control increases dramatically as new infestations expand. There are 97,000 acres of hydrilla in Florida water bodies. State appropriations exclusively for hydrilla control have hovered at $4 million, but these funds only cover control costs for 11 percent of the hydrilla problem that exists there. The State of South Carolina appropriated $2.5 million for control activities in 1995; these funds cover costs for only 5 percent of the 40,000 acres of hydrilla in South Carolina water bodies.

North Carolina has the opportunity to attack hydrilla at a time when less than 6000 acres are present in our water bodies. In North Carolina, hydrilla is the most rapidly expanding aquatic weed, infesting both large and small impoundments in the Piedmont. It now occupies 5800 acres in North Carolina lakes and ponds. If allowed to spread unchecked, hydrilla has the potential to colonize 54,000 acres in our Piedmont and mountain reservoirs and virtually all of our natural coastal lakes (80,000 surface acres). Alligatorweed has invaded over 5000 acres of creeks, canals, rivers, and cropland. Duckweed and filamentous algae are native plants that constitute a major nuisance in smaller water bodies wastewater treatment lagoons, and private ponds.

Exotic aquatic plants cause severe environmental impacts. These plants out-compete and displace native aquatic plants, which have much greater value for fish and wildlife food and habitat. Dense mats of vegetation reduce water quality beneath them and create conditions that are harmful to fish such as largemouth bass.

Economic impacts of aquatic weed infestations can be far-reaching and include damage to agriculture, industrial and municipal water use, navigation, and recreation. Alligatorweed costs farmers an estimated $170,000 annually, including chemical application and crop yield lost to weed invasion of fields. Submersed aquatic vegetation can drive up production costs for industries and municipalities by blocking canals and clogging water intakes. Duke Power Company estimated that it avoids annual expenditures of $835,000 by maintaining an aquatic weed control program. Aquatic weeds cost one industrial facility $350,000 over five years for control measures and equipment replacement. Over 100 industries in North Carolina could be affected by submersed aquatic vegetation. Based on recreational user studies conducted in Florida and by the Tennessee Valley Authority, a large reservoir can provide as much as $3 million annually in recreational benefits. If not controlled, aquatic weed infestations may reduce these benefits by as much as 90 percent.

Hydrilla is the biggest threat to North Carolina water bodies, ruining their natural beauty and disrupting water use. This weed also damages water quality and habitat for fish and wildlife. Alligatorweed is a serious threat to coastal water bodies and crops. Economic damages of aquatic weeds invading cropland, clogging intake structures, and infesting recreational areas run into the millions of dollars. To prevent these environmental and economic impacts, the Aquatic Weed Control Program promotes a proactive approach to aquatic weed control through annual surveys. These surveys are imperative for early detection and lowering control costs. Research and public education are encouraged to enhance the effectiveness of control activities. To further efforts of the Aquatic Weed Control Program, a North Carolina Aquatic Weed Action Plan has been formulated.

The North Carolina Aquatic Weed Action Plan makes five recommendations to improve aquatic weed control activities in the state:

- Control new weed infestations early to reduce damage and keep costs down;
- Find the most cost-effective control methods for weeds;
- Develop public support for the prevention and control of weed infestations;
- Eliminate the movement of noxious aquatic weeds into North Carolina by enforcing federal laws and regulations; and
- Stop the spread of weed infestations within North Carolina by enforcing the North Carolina Aquatic Weed Control Act and State Noxious Weed Regulations.

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GLOSSARY

AQUATIC ECOSYSTEM includes the relationships of organisms to each other and to the physical-chemical environment of a lake and watershed system.

BIOLOGICAL CONTROL invloves the use of other organisms, such as predators, parasites, and pathogens, for controlling aquatic weeds.

CHEMICAL CONTROL is the use of herbicides for controlling aquatic weeds. Efficacy of chemical treatment depends on type of herbicide used, application rate, methods of application, and length of contact period with the plant.

DESICCATE means to dry out thoroughly.

DIOECIOUS plants produce male and female flowers on separate plants. Both the male and female plant is needed for fertilization.

EMERSED PLANTS root in the soil under the water, with their stems growing through the water, and their leaves and flowers rising above the water surface.

EXOTIC PLANTS are introduced to new habitats from their native range. These plants become problems when they spread rapidly in the absence of the natural constraints that exist in their native range.

FLOATING PLANTS have buoyant structures at the base of the green plant which allow each individual plant to float like a small raft, trailing its roots in the water below.

LITTORAL ZONE is the shallow area of a lake between land and open water where aquatic vegetation grows.

MAINTENANCE CONTROL is annual "spot" chemical treatment of aquatic weeds in areas where large-scale treatment programs have brought widespread infestations under control.

MECHANICAL CONTROL includes raking, cutting, seining, and the use of machinery for controlling aquatic weeds.

MONOECIOUS plants produce both the male and female flowers on the same plant.

NATIVE PLANTS have originated in a particular region. They are beneficial for providing food and cover for wildlife because animals are specifically adapted to plants of that region.

NOXIOUS AQUATIC WEEDS grow in or are closely associated with the aquatic environment and are threats to public health or safety or to water uses.

NOXIOUS WEEDS are plants which are known to be vastly more damaging than beneficial.

OVERWINTERING buds of hydrilla, tubers and turions, keep the plant alive during the winter.

PHYSICAL CONTROL includes the use of dyes, physical barriers and water level manipulations for controlling aquatic weeds.

SUBMERSED PLANTS root in the bottom of a water body and their green growth is confined to the water column.

TRIPLOID GRASS CARP mature normally but are sterile because they have an extra set of chromosomes that produces abnormal gametes.

TUBER is an overwintering bud of hydrilla. Tubers are formed in the soil at the tip of downward growing stems and lay dormant in the soil until spring.

TURION is an overwintering bud of hydrilla. Turions form on the stem then drop to the soil and lay dormant until spring.

WEED is a plant "out of place" and implies damage of some sort, even if the harm is restricted to occupying a space that might be occupied by a more desirable plant.

PREFACE

This report was commissioned by the North Carolina General Assembly to determine the past, present, and potential future environmental and economic impacts caused by the spread of noxious aquatic weeds. A copy of the legislation is in the Appendix.

The information presented in this report was gathered from records of state agencies (North Carolina, South Carolina, Florida, California), public utilities (North Carolina, South Carolina, Tennessee Valley Authority), North Carolina industries, the North Carolina Cooperative Extension Service, scientific literature, and researchers (Florida, North Carolina, Tennessee Valley Authority) and was prepared by the Aquatic Weed Control Program of the North Carolina Division of Water Resources.

INTRODUCTION

In Pre-Columbian times, very few of our North Carolina water plants could have existed west of the outer coastal plain. The dense forests and lack of ponds and lakes would have excluded them. The coastal parts of our rivers, bay lakes, ponds in dune swales, and the North Carolina sounds would have provided the great majority of aquatic plant habitat within the state. The clearings of European settlers, mill ponds, livestock ponds, irrigation ponds, and (since the turn of the century) major multi-purpose reservoir construction have created extensive inland habitat for aquatic plants. Still, our native species have been slow colonizers and are only occasionally accused of being "weeds." The exotic aquatic plants that have managed to reach our shores from other continents are different. They tend to be aggressive colonizers and competitors. With few exceptions, the plants discussed in this report are illegal aliens. They are not supposed to be here, and they are just beginning to affect our water resources.

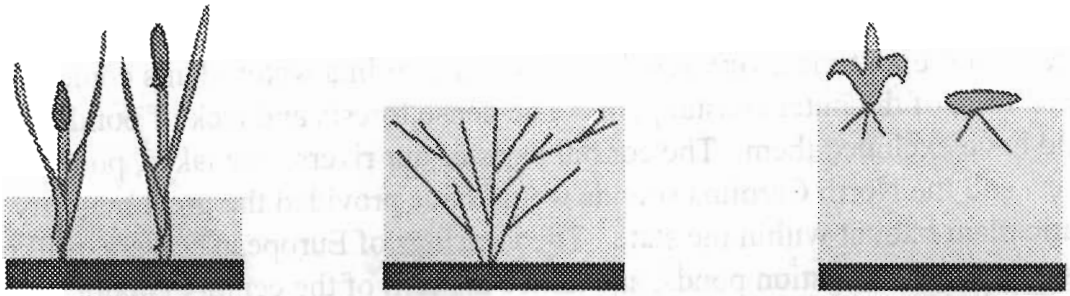
General Concepts

Algae are mentioned in several places in the report because they cause the majority of problems in the numerous very small water bodies throughout the state. All of the other plants discussed in this report are higher plants that flower and produce seeds. Watermeal, one of the duckweeds, is the smallest flowering plant (two or three will fit on the head of a straight pin).

All flowering plants developed on land. Our aquatic flowering plants each returned to the water, at some time in their history, probably to eliminate competition for light or to eliminate the energy required to produce erect stems like those of terrestrial plants.

Aquatic plants have three basic growth forms that determine where they can live and what kinds of effects they have on other living things, including us. The three growth forms are illustrated with some examples on the next page.

GROWTH FORMS OF AQUATIC PLANTS



EMERSED	SUBMERSED	FLOATING
Cattail	Hydrilla	Duckweed
Common Reed	Brazilian Elodea	Watermeal
Purple Loosestrife	Coontail	Water Hyacinth
Alligatorweed	Brittle Naiad	
Water Primrose	Eurasian Watermilfoil	
Water Lily	Bladderwort	
	Slender Naiad	
	Variable-leaf Milfoil	

Exotic species are underlined.

1) **Emersed plants** have made only a small step into the aquatic environment. They root in the soil under the water, with their stems growing through the water, and their leaves and flowers rising above the water surface. They have retained the erect stems of terrestrial plants and most of them can be grouped together as "marsh plants." They tolerate water and saturated soils but they do not require these conditions.

   Emersed plants are very depth-limited because most of the green parts of the plant must be above the surface. (Exception—Alligatorweed can form floating mats and is not depth-limited. Stems found close to shore are almost hollow and become more so as the plant extends into the water. This adaptation enables the plant to float on the water surface. As new stems are formed, old stems are forced under water. They then drop their leaves and generate rootlets at each node which absorb nutrients from the water. These floating mats provide anchorage and additional nutrients for new growth.)

2) **Submersed plants** have converted fully to aquatic life. They root in the bottom of a water body and their green growth is confined to the water column. They have pliable stems and leaves which are supported by the water. Submersed plants are dependant on the water in which they grow. If the water is removed, the above-ground parts of the plants will collapse and desiccate. Survival of a plant is dependent upon the size and resilience of its roots and other underground structures. Submersed plants, despite their apparent fragility, include several of the most invasive and damaging species that threaten our present and future water resources. They can grow to much greater depths than emersed plants. Hydrilla in Lake Gaston has been observed growing at a depth of 20 feet. It is not clear at this time whether or not it will reach the surface from this depth but hydrilla can easily form surface mats when growing at depths of less than 12 feet.

3) **Floating plants** have taken a completely different approach to the problem of invading aquatic environments. They have developed buoyant structures at the base of the green plant which allow each individual plant to float like a small raft, trailing its roots in the water below. Most of these plants reproduce very prolifically by "budding off" new plants (duckweeds) or by sending out new shoots which develop into "daughter plants." Daughter plants which remain connected to the parent (water hyacinths) help form floating mats or islands. Floating plants are not depth-limited and are free to go wherever the wind pushes them. They very easily completely cover small water bodies and great

aggregations of these plants can cover significant areas of large water bodies.

Weeds are plants "out of place." A rose bush is a weed in a corn field and corn is a weed in the rose garden. Weeds imply damage of some sort, even if the harm is restricted to occupying a space that might be occupied by a more desirable plant. **Noxious weeds** are those plants which, because of their nature and history, are known to be vastly more damaging than beneficial. **Noxious aquatic weeds** are defined in the North Carolina Aquatic Weed Control Act of 1991 (Article 15, Chapter 113A) as "any plant organism which: (1) grows or is closely associated with the aquatic environment, whether floating, emersed, submersed, or ditch-bank species and including terrestrial phases of any such organism; (2) exhibits characteristics of obstructive nature and either massive productivity or choking density; and (3) is or may become a threat to public health or safety or to existing or new beneficial uses of the waters of the State. (Please see the full text of the Act and its associated rules in the Appendix.)

The North Carolina Noxious Weed Act lists 28 noxious exotic aquatic plants, eight of which are present in North Carolina. Others threaten to enter our state. All of these plants threaten our state's water resources and reduce their beneficial uses. The North Carolina Aquatic Noxious Weed List is presented in Table 1 in the Appendix.

Eradication is a concept which should be used cautiously when dealing with infestations of noxious aquatic weeds established in natural water bodies. While it is easy to eradicate a shipment of hydrilla intercepted in an aquarium store, it will take a minimum of five or six years to determine if efforts to eradicate even a tiny patch of hydrilla from a natural water body have been successful. Control should be the first activity. Once the nuisance condition has been eliminated, the potential for eradication should be considered on a case by case basis.

HISTORY AND ROLE OF THE NORTH CAROLINA AQUATIC WEED CONTROL PROGRAM

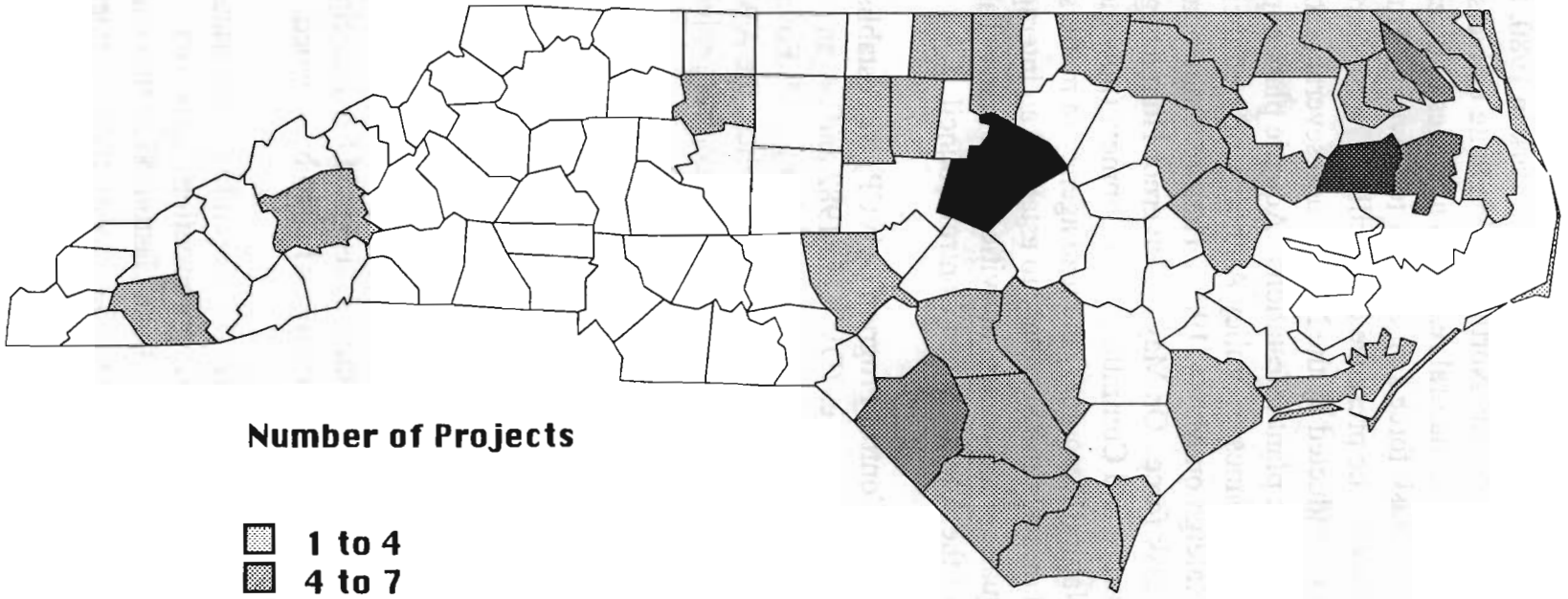
When hydrilla was discovered in Umstead Park in 1980, the North Carolina Department of Agriculture (NCDA) and North Carolina State University assembled an informal task force of members from natural resources agencies to discuss possible courses of action. In early 1982, the task force sent a report to Governor Hunt with conclusions regarding the threat caused by the presence of hydrilla in North Carolina, the results of a 1981 hydrilla survey conducted by the NCDA, and several recommendations for addressing the threat of noxious plant infestations. Aquatic plant experts from Florida, South Carolina, and the Tennessee Valley Authority offered their experiences in a workshop convened in Raleigh on May 4, 1982. Their recommendations supported those made earlier by the task force. On May 5, Governor Hunt designated the Department of Natural Resources and Community Development (now the Department of Environment, Health, and Natural Resources) the lead agency in matters related to aquatic plant problems and directed the Secretary to establish an interagency council to oversee and coordinate aquatic weed control activities in the state. Table 2 in the Appendix lists the membership of the Aquatic Weed Control Council.

The Aquatic Weed Control Program (AWCP) was established in the North Carolina Division of Water Resources (DWR) in 1982 and began hydrilla control activities in 1983. The program reached a full staff (Biologist II, Environmental Specialist I, and Environmental Technician I) in 1986. Since then, the AWCP has grown continuously in both the number and cost of aquatic weed control projects, while the number of staff has diminished.

Previously, the program was able to attract summer interns and graduate fellows to support the permanent staff; however, budget cuts eliminated these positions as well as the AWCP Environmental Specialist I position. Staff in the AWCP has been reduced from three to two full-time employees, one of which is paid from receipts. The AWCP has expanded from 17 control projects in 1986 to 46 projects in 1996, including Lake Gaston which involved 96 treatments. (See map on page 8.) The program hires a temporary technician in the summer, also paid from receipts. Because of staff shortage, the annual survey of weed infestations had to be dropped.

Through the late 1980's, the General Assembly appropriated $35,000 each year for aquatic weed control. In 1993, appropriations increased to $150,000 to help combat the explosive growth of hydrilla in Lake Gaston; $100,000 was used for hydrilla control in Lake Gaston and the remaining $50,000 was used for other control projects in the state.

AQUATIC WEED CONTROL PROJECTS
DIVISION OF WATER RESOURCES



NOTE: Lake Gaston = 200 separate sites

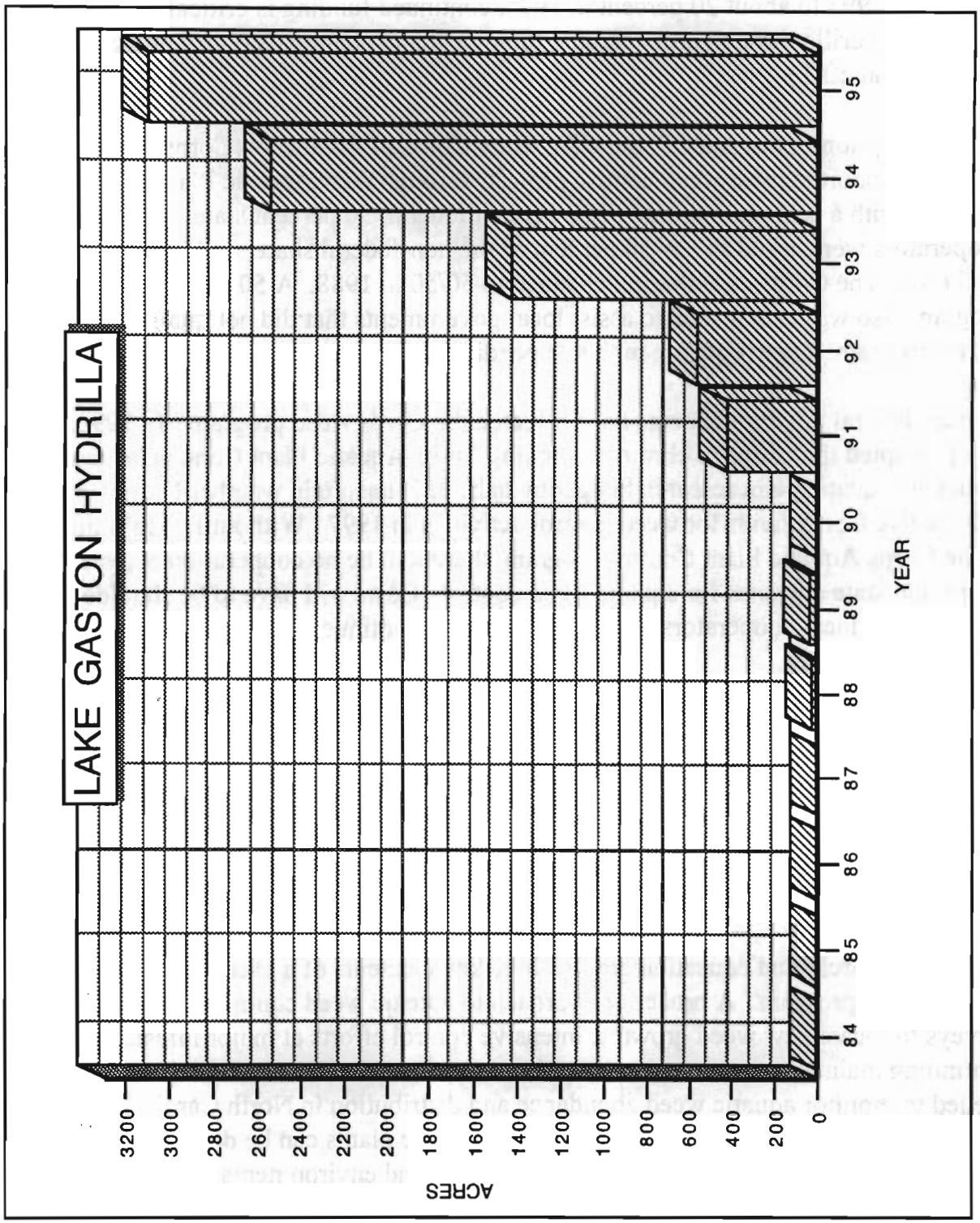
In 1994 and 1995, the General Assembly again appropriated $150,000 each year to continue efforts on Lake Gaston and other control projects. Despite the annual appropriations of $100,000 for Lake Gaston, hydrilla has increased in the lake each year since control efforts began. Although hydrilla expansion has slowed from 155 percent in 1993 to about 20 percent in 1995, continued funding is critical to control the spread of hydrilla through an integrated biological and chemical control program. (See figure on page 10.)

At the inception of the AWCP, the U.S. Army Corps of Engineers (Corps), Wilmington District, supported most weed control projects through their Aquatic Plant Control Program with a cost-sharing rate of 70 percent federal, 30 percent state. Local cooperators were asked to pay 50 percent of the non-federal share, or 15 percent of the total cost. The Corps cost-sharing changed to 50/50 in 1988. A 50/50 State/Local program also was established to assist local governments that did not qualify for the Corps program. (See brochure in the Appendix.)

Current federal government cuts have affected the Corps weed program. In 1996, these cuts prompted the Corps to eliminate funding for its Aquatic Plant Control Program and reduce its aquatic plant research budget by half. It is uncertain whether North Carolina will receive Corps funds for weed control activities in 1997. Without federal funding of the Corps Aquatic Plant Control Program, there will be no cooperation between the Corps and state agencies for aquatic weed control. Costs will have to be shouldered by the state and local cooperators if weed control is to continue.

The reduction in research funding has several effects, however, the most immediate will be the loss of the only federal funding source for aquatic plant research in universities. North Carolina State University lost its Corps funding in December 1995. There also will be a great reduction in research carried out by the Corps in their own laboratories at the Waterways Experiment Station in Vicksburg, Mississippi. Without this funding source, research on aquatic plant biology and on new control technologies will diminish.

Control, research, and education are the three key elements of a successful aquatic weed control program. A proactive approach to aquatic weed control includes annual surveys to locate new weed growths, intensive control efforts at major infestations, and continuing maintenance control to keep these weeds in check. An annual survey is needed to monitor aquatic weed abundance and distribution in North Carolina water bodies. By monitoring public waters, invasive exotic plants can be discovered and contained at low costs before they cause economic and environmental problems.


LAKE GASTON HYDRILLA
ACRES
3200
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2800
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200
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92
93
94
95
YEAR

Maintenance control hold reduces weed populations that are not harmful to water quality, fish and wildlife, and will not impact water uses. These are "spot" treatments of aquatic weeds in areas where the water use and water quality have been restored after large-scale treatment programs. Spot treatments are now used on North Carolina's eastern rivers, such as the Scuppernong and Alligator Rivers, to maintain alligatorweed at low levels, which will not interfere with navigation and recreation. Previously, large-scale chemical treatments were used to clear miles of these rivers that were impassable. Maintenance control of hydrilla has been achieved also with grass carp in many reservoirs in Wake and Granville Counties. Planting beneficial native species should be also considered in the AWCP as a part of control activities. By following control activities with the establishment of competitive native species, the reoccurrence of aquatic weed infestations might be slowed or prevented. Delaying further infestation at a site might result in lower overall control costs.

Research complements control. Understanding aquatic plant biology and aquatic ecosystems is critical when controlling nuisance weeds. Because interest in aquatic weed infestations typically does not occur until after a water body has been invaded, rate and distribution patterns of infestations are not well understood. Moreover, there is virtually no research on monoecious hydrilla, the dominant strain of hydrilla found in North Carolina. Most research has been conducted on dioecious hydrilla, the dominant strain found in Florida.

There are studies underway on Lake Gaston that include monitoring water movement, treating hydrilla using different herbicides at different application rates, and observing the life cycle of monoecious hydrilla. This information will be useful in scheduling herbicide treatments for those times when the plant is most vulnerable. However, each water body is unique and control methods of hydrilla may differ in other lakes. There is a need for more research on monoecious hydrilla in North Carolina.

Information about aquatic weed identification, biology, and control must be distributed to the public. No effort to combat the spread of hydrilla or alligatorweed will be successful without continued public awareness and cooperation. It is well known that aquatic weeds spread by human activities. Many hydrilla infestations begin near a boat ramp. Hydrilla strands can be carried on boat trailers and propellers and spread from one lake to another causing new infestations. Anglers who believe that hydrilla enhances fishing may purposefully introduce hydrilla into lakes.

To educate the public, the Aquatic Weed Control Council and the AWCP have posted warnings about the potential spread of hydrilla at various lakes. The Council's

Education committee occasionally prepares information about aquatic weed identification, biology and control and distributes pamphlets. Agents with the Cooperative Extension Service have been trained to assist with aquatic weed identification and control recommendations. The more the public understands about aquatic ecosystems, the more likely they will take actions to protect them.

PROGRAMS OF OTHER STATES

Florida began its aquatic weed control activities in the late 1800's. Water hyacinth, introduced earlier as an attractive ornamental plant, had taken over many miles of rivers and parts of the intracoastal waterway. Navigation with small boats was absolutely impossible in many areas and even ocean-going vessels were sometimes unable to make progress against the plants. When the hyacinths had been subdued, they were followed by rafts of another floating plant, water lettuce. Because of constant maintenance control with herbicide treatments, these plants are now only minor problems in Florida.

Hydrilla control became a major issue in the late 1970's. Large programs began in 1981 when $2 million was appropriated by the Florida Legislature for this purpose. Since that time, Florida appropriations for hydrilla control have waxed and waned. Every time control efforts have slackened, hydrilla has expanded its range in Florida lakes. (See graph on page 15.) The Florida aquatic plant management program will spend $9 million for hydrilla control in 1996, but only $2 million will be appropriated for 1997. [1] Again, the gains won against hydrilla in 1996 will be lost in 1997. Large sums will be needed in the future to get hydrilla on a downward track.

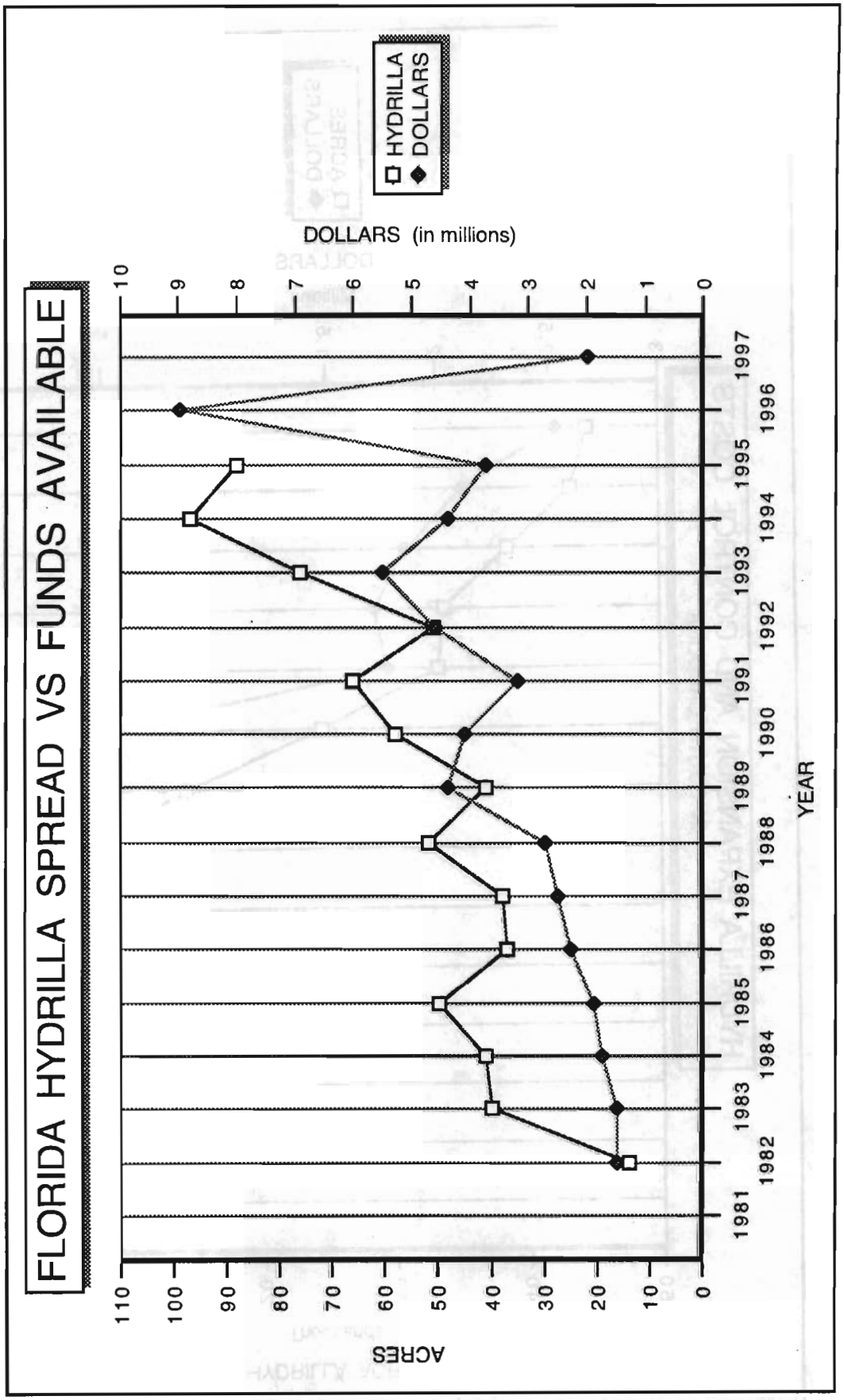
Hydrilla is present in 43 percent of Florida's 450 water bodies and occupies 97,000 acres, more than any other exotic or native plant.[2] A distant second to hydrilla are the native cattails which occupy 32,000 acres in the waters of the state. Florida is losing its struggle with hydrilla.

South Carolina began its attack on aquatic plants in the 1970's when the main problems were Brazilian elodea in the Santee-Cooper lakes and water hyacinth and alligatorweed there and elsewhere in the state. Hydrilla appeared in Lake Marion among the Brazilian elodea in 1982; both were subjected to herbicide treatments for the next few years. Hydrilla became the dominant plant in the system. By 1987, hydrilla had spread to Lake Moultrie and to two other reservoirs. Between 1989 and 1992, 400,000 sterile grass carp were introduced to upper Lake Marion and Lake Moultrie to help control it. Good results were obtained in Lake Marion but the carp did not thwart the spread of hydrilla in Lake Moultrie.

At the present time, hydrilla is known to occur in eight South Carolina reservoirs. In 1995, South Carolina spent $2.5 million to control 2171 acres of hydrilla, 4.9 percent of the amount known to be present in the state.[3] Lakes Wateree and Keowee, discovered to have hydrilla in 1994 and 1995, respectively, are close to the North Carolina border.

The history of hydrilla expansion and control costs in South Carolina is depicted graphically on page 16.

The experience of both states indicates where North Carolina may be headed if swift action is not taken to control hydrilla. The current AWCP would have to expand substantially to control the large infestations of hydrilla such as those present in Florida and South Carolina. There are 134,000 acres susceptible to colonization by hydrilla in North Carolina. With less than 6000 acres infested, this state has the opportunity to aggressively combat hydrilla before it spreads to that point.


FLORIDA HYDRILLA SPREAD VS FUNDS AVAILABLE
HYDRILLA
DOLLARS
DOLLARS (in millions)
ACRES
YEAR
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10
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30
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50
60
70
80
90
100
110
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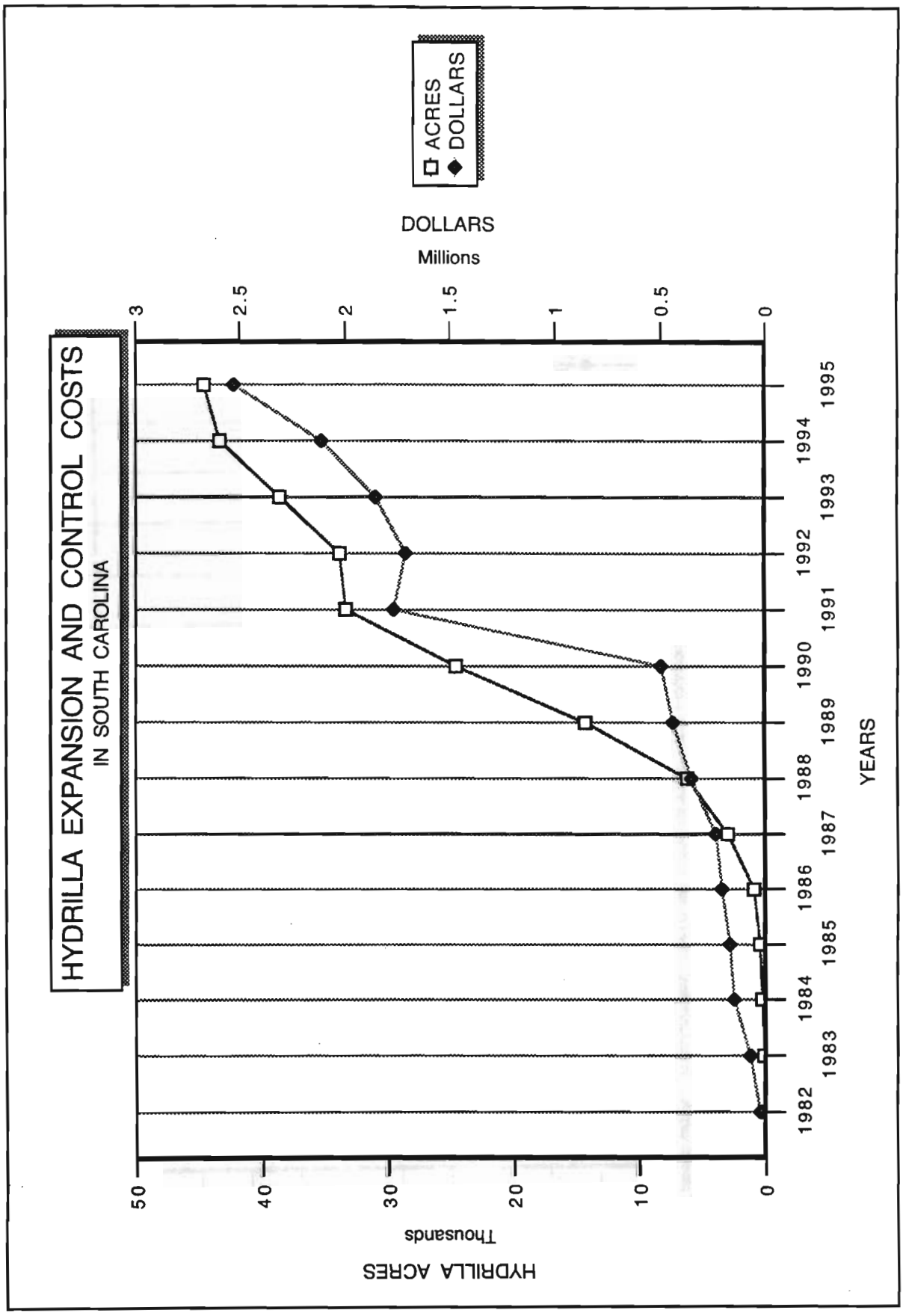
HYDRILLA EXPANSION AND CONTROL COSTS
IN SOUTH CAROLINA
ACRES
DOLLARS
DOLLARS
Millions
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2
1.5
1
0.5
0
HYDRILLA ACRES
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40
30
20
10
0
1982
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1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
YEARS

ENFORCEMENT OF AQUATIC WEED LAWS

The North Carolina Aquatic Weed Act of 1991 established a framework for control of noxious aquatic plants in North Carolina. The authority to regulate the "importation, sale, use, culture, collection, transportation, and distribution of a noxious aquatic weed" was granted to the Commissioner of Agriculture under Article 36, Chapter 106 of the General Statutes.

Within the North Carolina Department of Agriculture (NCDA), the Plant Protection Section has been delegated this authority. Plant Protection Specialists in the state are responsible for all quarantines related to insects, diseases, and noxious weeds, terrestrial or aquatic. Specialists contact greenhouses, nurseries, garden centers and other establishments where risk of plant pest spread is high. In addition, personnel conduct monitoring and detection surveys to determine the movement of potential plant pests. Although contacts and inspections have been made at aquatic plant dealer locations, additional personnel are needed to increase the number and timeliness of inspections.

The Federal Noxious Weed Act of 1974 prohibits the importation and distribution of noxious weeds into the United States except under certificate or permit from the U.S. Department of Agriculture. Species listed on the Federal Noxious Weed List are subject to enforcement by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS). Under the current interpretation, quarantines must be established for listed noxious weeds to prevent interstate movement. Witchweed is the only noxious weed for which a quarantine has been established.

The Federal Noxious Weed Control Improvement Act of 1995 (S690) was introduced into Congress in April 1995 and corrects many of the deficiencies found in the current statute. In addition, APHIS is involved in a project to combine all federal regulations associated with plant pests under one authority, the Consolidated Plant Pest Act. These measures may improve federal enforcement of interstate traffic in noxious aquatic plants.

The Lacey Act of 1900 (950 CFR 16) directs the U.S. Fish and Wildlife Service (USFWS) to enforce movement of noxious weeds. The USFWS is primarily concerned with the importation of harmful species including fish, wildlife, and plants. The Lacey Act can be enforced at state boundaries only when both states prohibit the movement of a particular species. If only one state has a noxious weed control law in place, interstate transfer can still occur and is not prohibited by the Lacey Act. Although

North Carolina has a law that prohibits movement of noxious aquatic weeds into our state, plants are still brought in and move through the state because our neighboring states, Virginia, Tennessee, and Georgia, do not regulate movement of noxious aquatic weeds. South Carolina is the only neighboring state with a noxious aquatic weed law.

THE STATUS OF AQUATIC WEEDS IN NORTH CAROLINA

Aquatic weeds that maintain large infestations in North Carolina public waters are hydrilla, alligatorweed, and Eurasian watermilfoil. Hydrilla is the most rapidly expanding aquatic weed, infesting both large and small impoundments in the Piedmont. (See map on page 20.) Since hydrilla's discovery in North Carolina in 1980, the number of confirmed hydrilla infestations in water bodies throughout the state has increased from 11 to 81, for a total of 5800 acres of hydrilla. Because no surveys have been conducted since 1989, it is likely that the actual number of infestations is larger. Alligatorweed has become a major pest to agriculture and continues to invade the state's most scenic eastern rivers while extending its range into the Piedmont region. (See map on page 20.) Eurasian watermilfoil persists in Currituck Sound with a current estimate of 4000 acres. Other species on the rise are brittle naiad and Brazilian elodea, which like hydrilla cause problems in ponds and lakes. The graph on page 21 depicts acres of hydrilla treated versus acres of alligatorweed treated by the AWCP.

EXOTIC NOXIOUS WEEDS

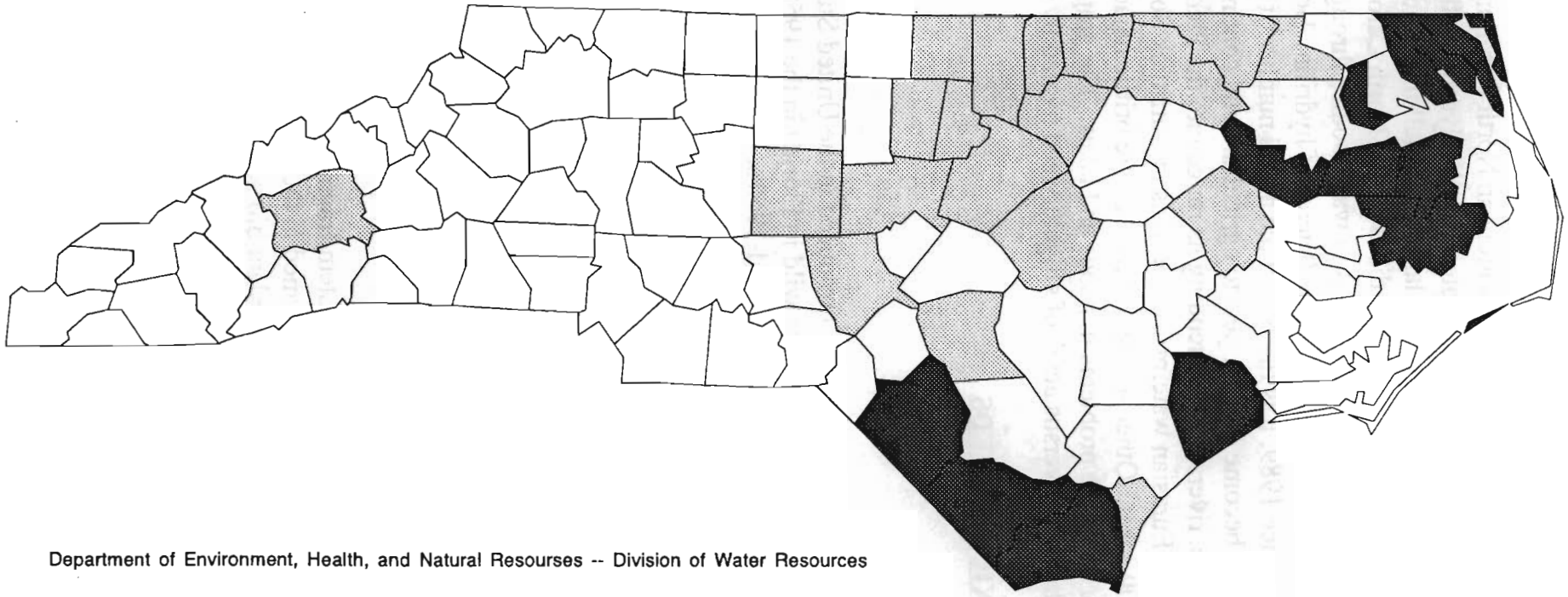
Hydrilla

Originally from Africa, hydrilla was introduced in the United States for use as an aquarium plant. It was found growing wild in Florida in the 1950's but was not correctly identified as hydrilla until the mid-1960's. There are two distinct strains, monoecious and dioecious. Each has a different life cycle. Monoecious hydrilla produces both male and female flowers, sets seed, and most of the leaves and stems die in the winter. Monoecious hydrilla is the dominant strain in North Carolina. Dioecious hydrilla only produces female flowers, does not produce seeds, and plants survive during the cold months. Dioecious hydrilla is found in Florida and South Carolina and has been identified in Wilmington and mixed with monoecious populations in Lake Gaston. Dioecious hydrilla is also found across the Gulf coast and in Texas, Arizona and California. Other infestations of monoecious hydrilla are in Virginia, Washington DC, Delaware, California, and in the Savannah River on the Georgia-South Carolina border.

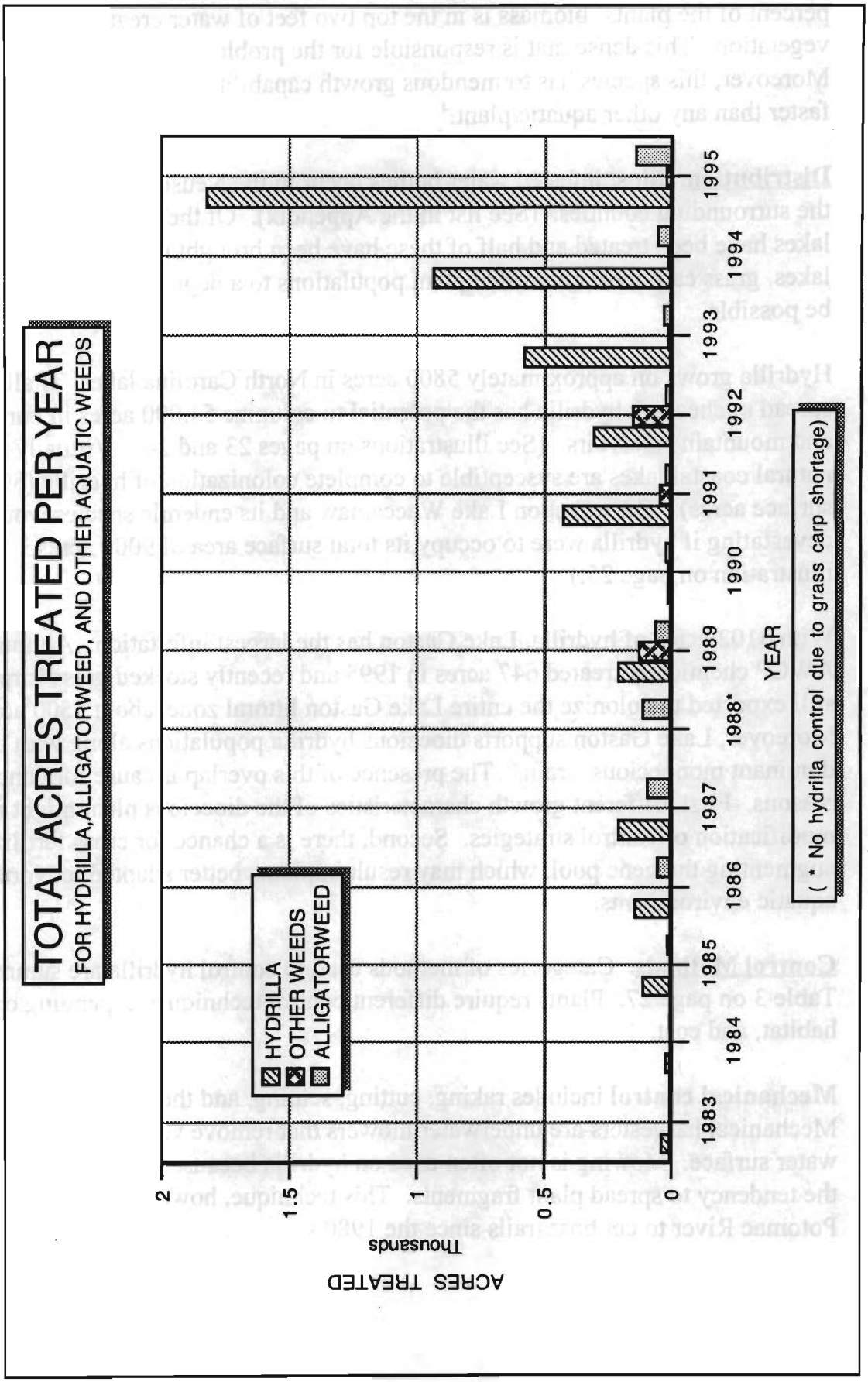
New hydrilla plants sprout from viable stem fragments and two kinds of overwintering buds, tubers and turions. Tubers are formed in the soil at the tip of downward growing stems. Tubers produce the majority of plant biomass the following spring. Turions form on the stem then drop to the bottom. Both tubers and turions lay dormant in the soil until spring, then sprout into new plants. When a plant sprouts, it produces many

MAJOR AQUATIC WEED PROBLEMS IN NORTH CAROLINA

Hydrilla = Gray Alligatorweed = Black



Department of Environment, Health, and Natural Resourses -- Division of Water Resources


TOTAL ACRES TREATED PER YEAR
FOR HYDRILLA, ALLIGATORWEED, AND OTHER AQUATIC WEEDS
HYDRILLA
OTHER WEEDS
ALLIGATORWEED
ACRES TREATED
Thousands
2
1.5
1
0.5
0
1983
1984
1985
1986
1987
1988*
1989
1990
1991
1992
1993
1994
1995
YEAR
(* No hydrilla control due to grass carp shortage)

stems from the base of the plant that rise to the surface. At maximum growth, 70 percent of the plants' biomass is in the top two feet of water creating a dense mat of vegetation. This dense mat is responsible for the problems caused by hydrilla. Moreover, this species has tremendous growth capabilities and can increase its biomass faster than any other aquatic plant.[4]

Distribution. Most infested water bodies occur in the Neuse River Basin in Wake and the surrounding counties. (See list in the Appendix). Of the 81 known infestations, 40 lakes have been treated and half of these have been brought under control. In many lakes, grass carp have controlled plant populations to a degree where eradication could be possible.

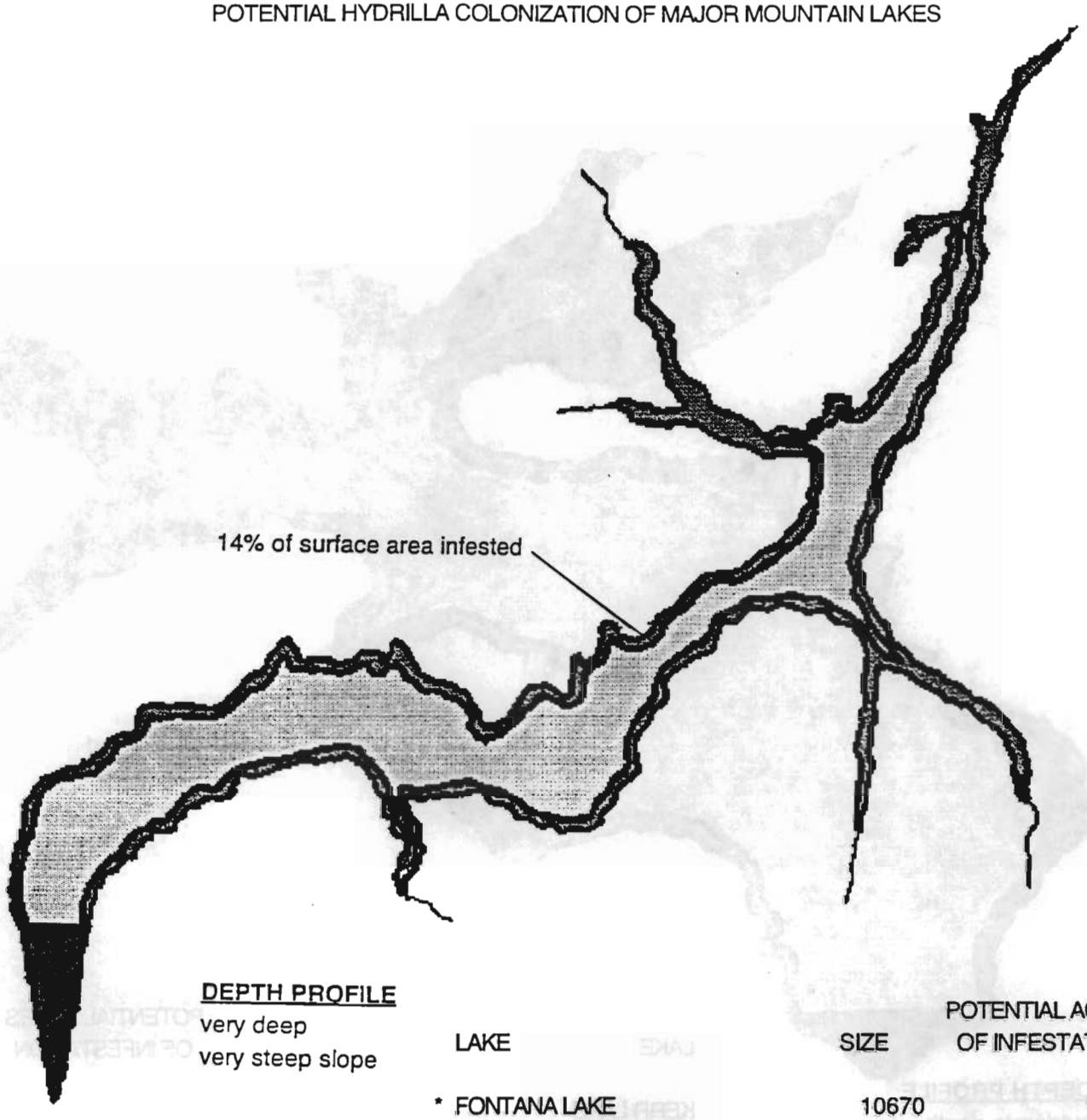
Hydrilla grows on approximately 5800 acres in North Carolina lakes. If allowed to spread unchecked, hydrilla has the potential to colonize 54,000 acres in our Piedmont and mountain reservoirs. (See illustrations on pages 23 and 24.) Virtually all of our natural coastal lakes are susceptible to complete colonization of hydrilla (80,000 surface acres). The effect on Lake Waccamaw and its endemic species would be devastating if hydrilla were to occupy its total surface area of 9000 acres.[5] (See illustration on page 25.)

With 3102 acres of hydrilla, Lake Gaston has the largest infestation. Although the AWCP chemically treated 647 acres in 1995 and recently stocked grass carp, hydrilla is still expected to colonize the entire Lake Gaston littoral zone, about 5500 acres. Moreover, Lake Gaston supports dioecious hydrilla populations along with the dominant monoecious strain.[6] The presence of this overlap is cause for concern for two reasons. First, different growth characteristics of the dioecious plant might require modification of control strategies. Second, there is a chance for cross fertilization, augmenting the gene pool, which may result in plants better adapted to North Carolina's aquatic environments.

Control Methods. Categories of methods used to control hydrilla are summarized in Table 3 on page 27. Plants require different control techniques depending on species, habitat, and cost.

Mechanical control includes raking, cutting, seining, and the use of machinery. Mechanical harvesters are underwater mowers that remove vegetation beneath the water surface. Mowing is not often used on hydrilla because of the prohibitive cost and the tendency to spread plant fragments. This technique, however, has been used in the Potomac River to cut boat trails since the 1980's.

POTENTIAL HYDRILLA COLONIZATION OF MAJOR MOUNTAIN LAKES

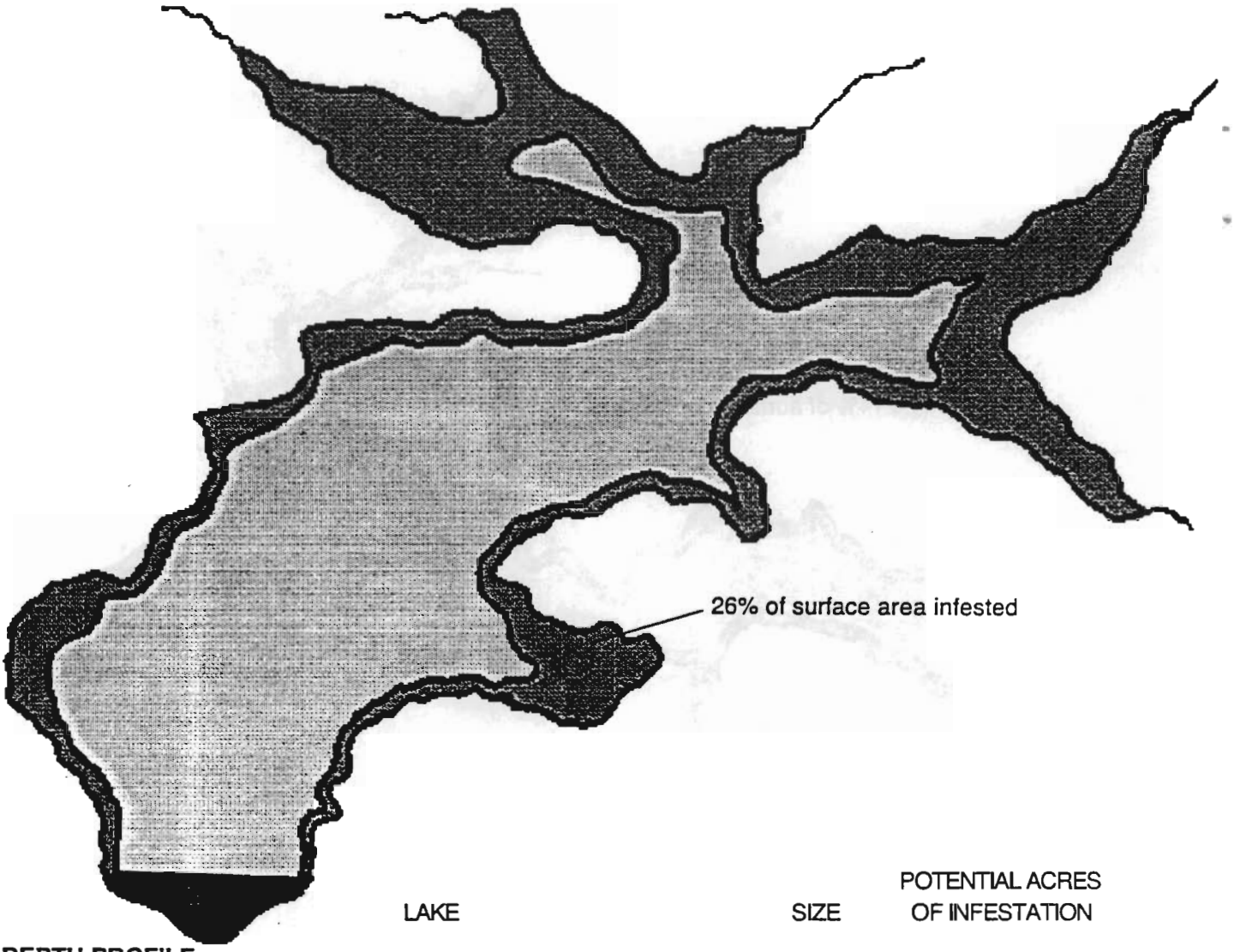


DEPTH PROFILE
very deep
very steep slope

LAKE	SIZE	POTENTIAL ACRES OF INFESTATION
* FONTANA LAKE	10670	1494
* CHATUGE LAKE	6950	973
LAKE JAMES	6510	911
* HIWASSEE LAKE	6275	879
LAKE HICKORY	4100	574
LAKE RHODHISS	3515	492
SANTEETLAH LAKE	2850	399
NANTAHALA LAKE	1605	225
LAKE LURE	1500	210
THORPE RESERVOIR	1462	205
LOOKOUT SHOALS LAKE	1270	179
APALACHIA LAKE	1100	154
TOTAL ACRES	47807	6695

* Lakes measured to determine regional average.

POTENTIAL HYDRILLA COLONIZATION OF MAJOR PIEDMONT LAKES

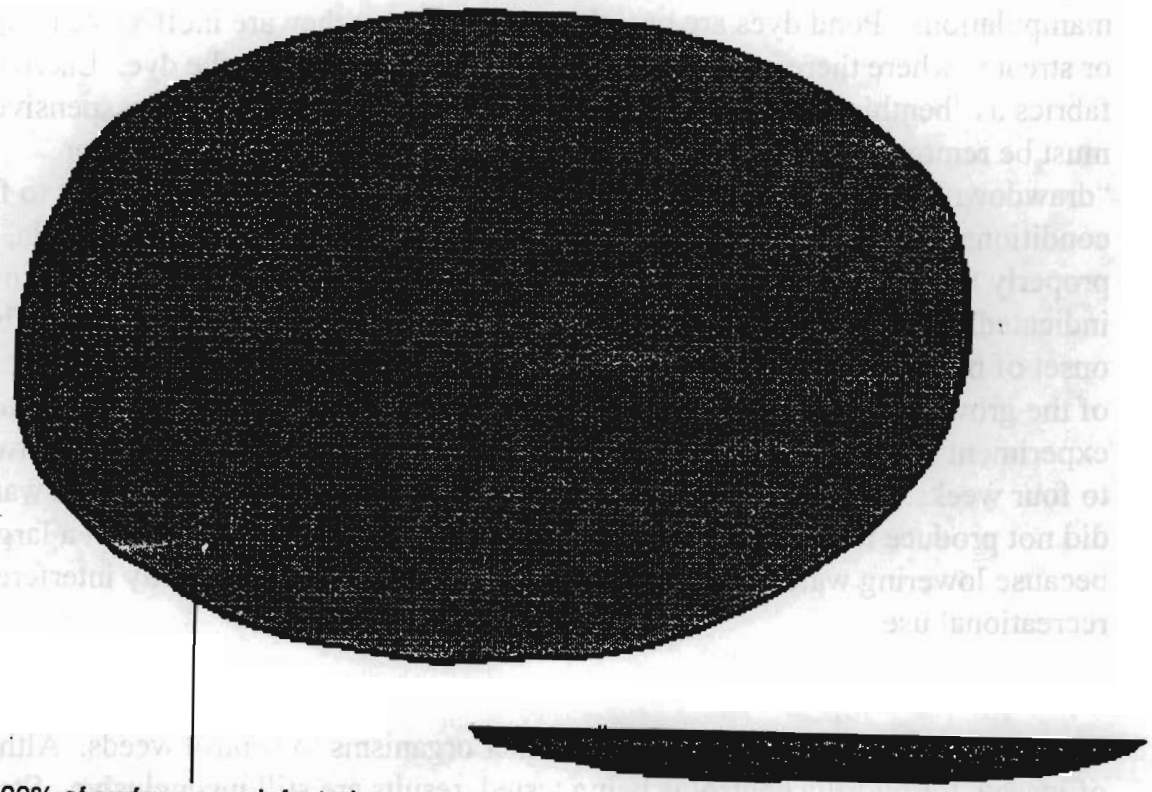


DEPTH PROFILE
moderate depth
moderate slope

	LAKE	SIZE	POTENTIAL ACRES OF INFESTATION
	KERR LAKE	49000	12740
	LAKE NORMAN	32510	8453
	LAKE GASTON	20300	5278
	HIGHROCK LAKE	15750	4095
*	B. EVERETT JORDAN LAKE	14300	3718
*	FALLS OF THE NEUSE LAKE	12490	3247
	LAKE WLYIE	12450	3237
	BLADIN LAKE	5350	1391
	LAKE TILLERY	5264	1368
*	HARRIS LAKE	4150	1079
*	HYCO LAKE	3750	975
*	MAYO LAKE	2800	728
	TUCKERTOWN	2550	663
	TOTAL ACRES	180664	46972

* Lakes measured to determine regional average.

POTENTIAL HYDRILLA COLONIZATION OF MAJOR COASTAL LAKES



100% of surface area infested

DEPTH PROFILE
very shallow
very little slope

LAKE	SIZE	POTENTIAL ACRES OF INFESTATION
* LAKE MATAMUSKEET	42000	42000
* PHELPS LAKE	16600	16600
* LAKE WACCAMAW	8950	8950
ALLIGATOR LAKE	5500	5500
PUNGO LAKE	3000	3000
BAY TREE LAKE	1400	1400
* WHITE LAKE	1050	1050
LAKE SINGLETARY	572	572
GREENFIELD LAKE	115	115
TABOR LAKE	70	70
TOTAL ACRES	79257	79257

* Lakes measured to determine regional average.

Physical control includes the use of dyes, physical barriers and water level manipulations. Pond dyes are not often used because they are ineffective in open lakes or streams where there is substantial water exchange to dilute the dye. Likewise, fabrics as "benthic barriers" are not used because they are extremely expensive and must be removed and cleaned periodically. Water level manipulations, or "drawdowns," are generally implemented in the winter to expose the plant to freezing conditions. Although a winter drawdown is ineffective in controlling hydrilla, a properly timed summer drawdown may be a feasible option as recent research has indicated. If water levels were lowered after the sprouting of new plants and before the onset of new tuber production, hydrilla possibly could be eliminated for the remainder of the growing season.[7] Researchers at North Carolina State University conducted an experiment in which young hydrilla plants were exposed to a drawdown for two weeks to four weeks. These plants did not regrow after being resubmerged in the water and did not produce tubers and turions. This technique has not been used on a large-scale because lowering water levels during the summer would significantly interfere with recreational use.

Biological control involves the use of other organisms to control weeds. Although use of insects for hydrilla control is being tested, results are still inconclusive. Sterile grass carp are the only biological control agents that are used extensively. Historically, grass carp use was prohibited until techniques were developed to produce a sterile grass carp. Sterile or "triploid" carp mature normally but are sterile because they have an extra set of chromosomes that produces abnormal gametes. This breakthrough, coupled with improved methods for testing for triploidy in individual fish, encouraged the use of certified triploid grass carp. Grass carp have been the most effective and least expensive method to control hydrilla in North Carolina and elsewhere. Stockings are controlled by the Wildlife Resources Commission (WRC) through a permitting process. The WRC and the Division of Marine Fisheries have expressed concern about large grass carp stockings in some lakes because it may be possible for the fish to escape into non-target lakes, rivers, and estuaries. A telephone survey of coastal southeastern states did not reveal any evidence that would substantiate these concerns.

Chemical control is a common method of aquatic weed control. The AWCP uses aquatic herbicides where grass carp are inappropriate or unavailable. Because most herbicides are non-selective, there may be adverse impacts to non-target vegetation; however, there are few native plants present in hydrilla infestations. Chemicals most frequently used for hydrilla control are: Copper (copper sulfate and organic copper

Table 3. Control Methods used for Hydrilla

	Technique	$/Acre/Year	Application	Advantages	Disadvantages
MECHANICAL	Harvesting	$3000-6000	Mid-summer	• Control around water intakes • Immediate results	• Ineffective in shallow water • Plant waste requires disposal • Removes desirable animals and plants
PHYSICAL	Drawdown	Negligible	Mid-summer 5-10 feet	• Effective in shallow areas • Inexpensive	• May reduce recreational uses • Promotes erosion • Depends on main use of water body
BIOLOGICAL	Grass Carp	$16-24	15-20 Fish per Vegetated Acre for Long-term Control	• Long-term control • Reduced environmental concerns	• Potential for escapement • May eliminate desirable plants
CHEMICAL	Contact Herbicides	$400-800	Mid-summer	• Site specific • Rapid response	• May have water use restrictions • Short-term control

complexes), diquat, endothall (Aquathol and Hydrothol formulations), and fluridone (Sonar). Aquatic herbicides are registered for use by the U. S. Environmental Protection Agency (EPA). These products undergo years of rigorous testing for safety. Nonetheless, some members of the public continue to be concerned about herbicide use in water. Currently, research is being conducted at Lake Gaston to improve herbicide application methods for hydrilla control. This study is a joint effort between North Carolina State University, the U.S. Army Corps of Engineers, and private industry. The hydrilla life cycle, herbicide rates, delivery systems, and effects of water movements are all being investigated.[8] Prior to this study, nearly all federally funded hydrilla research had been performed on the dioecious strain. Results of this study will be valuable in treating hydrilla in other water bodies as well as Lake Gaston. Currently, there are no state-supported research projects underway in North Carolina.

Alligatorweed

Alligatorweed, native to Argentina, has been established in North America since the early 1900's. Presently, it is found throughout the South Atlantic and Gulf Coast States and is present in California. In North Carolina, alligatorweed is found predominately in the Coastal Plain, where it has been a problem since the late 1950's. Alligatorweed can be found on dry soil, in swampy areas, and in open water. It usually occurs rooted along shorelines of fresh water bodies and in shallow areas with little wave action. Hollow stems enable the plant to float on the water surface. As new stems grow, the old ones are forced under water to form dense underwater mats that may be three to four feet thick. Although alligatorweed has conspicuous white flowers through the growing season, it has not been known to fruit or set seed in North America.[9] Reproduction is through plant fragmentation.

Distribution. Alligatorweed is most prevalent between the Virginia border and the counties north of the Pamlico River. About 5000 acres of alligatorweed infest cropland, creeks, canals, and rivers which drain into the Albemarle Sound. It causes major impacts in the upper narrow river reaches where mats form that extend from one side of the water body to the other. Blockage of waterways frequently occurs where fallen trees span the width of the stream.

Alligatorweed is also found in the southeastern counties from Onslow, Jones, and Lenoir Counties to the state line. Minor problems have occurred on the New River, Northeast Cape Fear River, Greenfield Lake in Wilmington, canals surrounding Lake Waccamaw, and canals in Robeson and Brunswick Counties. Piedmont infestations of

alligatorweed have been reported in Mecklenburg, Vance, Johnson, Moore, and Lee Counties.

Alligatorweed management has shifted from large treatments of rivers to maintenance control in nearly all of the mentioned sites. Treatment of alligatorweed began in 1983, when large expanses of coastal rivers and streams were blocked by mats of alligatorweed. These waterways have been cleared through repeated chemical treatments, and presently, receive maintenance treatments for plants that still exist along the shoreline and in marsh areas. Maintenance control is done annually to ensure that mats of alligatorweed do not interfere with navigation and recreational access. The table below lists the major sites of alligatorweed treatment by the AWCP.

Major Sites	Initial Coverage	River Miles	Present Coverage
Alligator River	19.0 acres	9.0	7.0 acres
Lumber River	33.25 acres	19.8	1.5 acres
Pasquotank River	15.5 acres	6.2	2.0 acres
Scuppernong River	9.5 acres	16.1	3.0 acres
Sweetwater Creek	17.5 acres	4.8	1.0 acres

This table illustrates how alligatorweed's aggressiveness allows it to become a serious problem when not controlled. Initially, 33 acres of alligatorweed blocked 20 miles of the Lumber River. Due to the magnitude of the infestation, alligatorweed treatments were broken into small blocks and treated throughout the summer

Alligatorweed has been contained in the Lumber and other rivers because treatment plans were site specific. The need for control depends on the extent of infestation, the desired use of the water system and access to the site. The acres of alligatorweed that remain in the Coastal Plain either are not causing problems or occupy abandoned cropland where no control techniques have been successful.

Control Methods. Table 4 on page 30 lists control methods for alligatorweed. **Mechanical control**, or machinery has been utilized to remove terrestrial alligatorweed by the DOT. In aquatic settings, the AWCP and the DOT use **aquatic herbicides** to control alligatorweed. The herbicide most often employed for alligatorweed control has the glyphosate as the active ingredient (Rodeo).

Table 4. Control Methods used for Alligatorweed

	Technique	$/Acre/Year	Application	Advantages	Disadvantages
Mechanical	Draglines	$1000	Mid-summer	• Immediate results • No water use restrictions	• Fragentation promotes spread of alligatorweed • Plant waste requires disposal
Biological	Flea Beetle	Not applicable	Early summer	• Long-term control • Reduced environmental concerns	• Repeated releases necessary • Population survival depends on climate
Chemical	Systemic Herbicides	$800	Mid-summer	• Site specific • Effective	• Repeat treatments necessary

In other parts of the United States, alligatorweed is primarily controlled **biologically** with flea beetles and other insects. The same insects are present in North Carolina and do suppress alligatorweed temporarily in some areas. North Carolina State University has been monitoring these insect populations and their effectiveness in controlling alligatorweed. They have caused some damage to weed mats, but cold winters have prevented their widespread establishment here.[10]

Eurasian Watermilfoil

Eurasian watermilfoil is a submersed plant from Europe that invaded Currituck Sound in the early 1960's. By 1966, the plant occupied more than 66,690 acres and extended into Back Bay, Kitty Hawk Bay and other embayments of the Albemarle Sound system. During 1977 and 1978, however, plant biomass dramatically declined primarily due to increased suspended sediment and other factors.[11]

This plant seemed to be limited to the coastal sounds until it was discovered inland in Lake Gaston and Roanoke Rapids Lake in 1992. In Roanoke Rapids Lake, it is estimated that coverage is about 33 percent of the surface area. Because this weed has not been found in other North Carolina inland water bodies in 30 years, it is speculated that introduction was deliberate.

Approximately 4000 acres of Eurasian watermilfoil is still present in the Currituck and Albemarle Sounds. Any body of water that is connected to the Sound is susceptible to infestation by Eurasian watermilfoil.[12] The AWCP has been solicited by municipalities along the Currituck Sound for control of Eurasian watermilfoil. However, state fisheries agencies believe that Eurasian watermilfoil serves as cover for larval and juvenile fishes. Fisheries agencies rely on the Coastal Area Management Act (CAMA) to prevent control of Eurasian watermilfoil. CAMA rules protect all submersed vegetation in North Carolina estuaries. Although AWCP activities are exempt from these rules (N.C. Administrative Code T15A: 07H.0208), it is the policy of DWR and the Aquatic Weed Control Council to acknowledge the concerns of other coordinating agencies. The AWCP, therefore, does not support projects that involve Eurasian watermilfoil control. The AWCP believes that if the worst infestations of Eurasian watermilfoil were controlled, new techniques could be developed to protect and enhance native plant communities in the coastal area.

Control Measures. The only feasible control method for Eurasian watermilfoil is **chemical control.** In 1988, the AWCP treated a boat marina and a canal system in Jean

Guite Creek for the Town of Southern Shores and a pier and recreational access area in Kitty Hawk Bay for the Town of Kill Devil Hills (Dare County). In both cases, 2,4-D (2,4-dichlorophenoxyacetic acid) was used, producing good results in Southern Shores and poor results in the open water of Kitty Hawk Bay. In 1993, the AWCP treated two acres of the Perquimans River for Camp Cale. The plants were a nuisance to swimmers. Again 2,4-D was used. Although the Eurasian watermilfoil was controlled at the site, effects on native species were observed downstream. For this reason, the WRC is skeptical about the use of 2,4-D in the Currituck Sound. Two, four-D is selective for broad-leafed plants like Eurasian watermilfoil and usually does not harm native plants because none are broad-leafed plants. More interagency coordination on this issue is on-going and will be beneficial in managing the estuarine ecosystem.

POTENTIAL PROBLEM WEEDS

There are other noxious aquatic plants, though not presently widely distributed in North Carolina, that have the potential to seriously damage our water uses and ecosystems. The most threatening species are purple loosestrife, hygrophila, and giant salvinia.

Purple loosestrife is a marsh plant which was introduced to the U.S. for landscaping. It has spread widely in wet environments in the northern half of North America, displacing native species which provide food and cover for wildlife. Purple loosestrife is not used by wildlife. It has been present in North Carolina since the 1970's. Spot infestations currently occur in Forsyth, Washington and Guilford Counties. The plant is also found in landscape plantings across the state. The NCDA issued 24 violations in 1994 and six in 1995 of State Noxious Weed Rules at nursery locations.

Hygrophila was encountered by the NCDA last year. Two isolated importation violations occurred at pet shops in Craven and Cumberland Counties; their supplier was from Virginia. Introduced in the United States in 1945, it was found established in the canals of Miramar, Florida in 1980. As hydrilla is being controlled in Florida, hygrophila is taking its place.[13] Hygrophila has been used extensively as aquarium plants and is transported by aquatic plant dealers from south Florida to other states. Little is known about the biology of hygrophila. Control is very difficult because it is resistant to registered aquatic herbicides.

Giant salvinia, also known as water fern and karibaweed, was reported in South Carolina in 1995. It is one of the world's worst weeds, occurring throughout Africa, Asia, the South Pacific, and South America. It is rarely found in the United States.

Giant salvinia is a free-floating aquatic fern that forms very dense mats, much like water hyacinth. The South Carolina infestation occurred in a small plantation pond. State agencies began control efforts as soon as the plant was identified.

NATIVE NOXIOUS WEEDS

Aquatic Weed Survey

The DWR conducted a survey among county offices of the Cooperative Extension Service to determine which aquatic weeds were a nuisance in each county. Sixty-four counties responded and each Cooperative Extension District was represented. Most of the reported infestations throughout the state were located on private property. The most troublesome weeds were filamentous algae and duckweeds. Both form thick mats over the water surface. Although not on the State Noxious Aquatic Weed List, they are widespread nuisances and difficult to control.

Algae

Nuisance algae commonly found in North Carolina farm ponds, wastewater treatment lagoons, and irrigation canals are filamentous blue-green algae or green algae. Although most algae are invisible without a microscope, filamentous algae form long strands that can be seen with the naked eye. They form thick clumps of floating vegetation that decompose, creating foul odors and taste problems as well as interfering with irrigation and recreation. Filamentous algae reproduce by several means, including fragmentation. Most species have overwintering forms that persist in the sediment.

Other species of bluegreen algae also produce toxins which lead to fish kills and cause death in cattle that drink infested water. Although no deaths have been reported east of the Mississippi River, there might be some effect on animal health due to algal toxins. The blue-green alga, *Lyngbia*, produces chemicals called geosmins which are responsible for the "muddy" taste in surface water supplies [14] and in the flesh of farm-raised catfish.[15] During high growth periods in lakes and ponds, geosmins can escape to the air and cause irritation in the respiratory membranes of humans. [16] A toxin produced by *Lyngbia* has been shown to produce a skin irritation in swimmers, "swimmer's itch."[17] This same substance is a potent tumor-producing agent [18] in addition to two other tumor-producing agents that have been isolated from *Lyngbia.*[19]

Control Measures. Control methods for filamentous algae are limited. Although

reduction in nutrient levels seems to be most effective, it usually is not a feasible option. Algicides are most often employed for control. Copper in the form of copper sulfate pentahydrate is most commonly used because it has little effect on other aquatic vegetation at normal application rates. There are concerns, however, about the toxicity of copper on fish and other animals if used repeatedly. Some states, including Virginia, have passed stringent regulations regarding copper use in water bodies.

Duckweed

Duckweed is most abundant in stagnant waters with high nutrient levels, such as farm ponds and backwater areas. This plant clogs water intakes, shades out desirable vegetation, and causes depletion of oxygen necessary for fish respiration. Duckweeds are found in wastewater treatment lagoons where they interfere with treatment processes. The AWCP is working with several municipalities to restore their wastewater treatment plants by removing duckweed and filamentous algae.

Control Methods. The only effective control method recommended for duckweed is herbicide treatment. When herbicides are used in wastewater systems that have spray fields, there are some concerns about the chemicals leaching into the soil and damaging vegetation. These concerns may be ungrounded because herbicides registered for aquatic use move very poorly in soil.

ENVIRONMENTAL IMPACTS OF NOXIOUS AQUATIC WEEDS

When plants move from the place where they evolve to a different habitat, they generally leave the diseases, parasites, competitors, and animals that feed upon them behind. Unfettered by these natural checks and balances, they grow aggressively in new environments. These exotic plants frequently have a competitive advantage over the native plants they encounter that are affected by natural enemies and competitors. Although there may be times, in the early stages of infestation, when introduced aquatic weeds are environmentally neutral or provide temporary benefits to fish and wildlife, they usually grow at such rapid rates that the benefits are soon negated. Exotic noxious weeds have these effects:

- Displace native plants.
- Completely dominate aquatic ecosystems and reduce habitat diversity.
- Often provide less food for wildlife than the species they replace.
- Reduce water quality.
- Reduce fish habitat.
- Increase numbers of insect and snail vectors of disease and nuisance flies.

The most common argument against controlling noxious weeds is the belief that they improve sportfish populations. Noxious aquatic weeds typically reach levels of abundance that inhibit, rather than improve, sportfish populations. Noxious weeds like hydrilla reduce fish habitat and, in doing so, concentrate the fish at the boundary between weeds and open water. This concentration of sportfish improves angler success rate and creates the illusion of an enhanced fish stock.

Fish habitat is substantially reduced in situations when heavy submersed weed growth reaches the surface and spreads out horizontally. The density of the weed growth can cause stunting of fish due to lack of predation and overcrowding. Predator fish, such as largemouth bass, cannot find smaller fish to feed on in heavy weed growths and therefore, do not grow at normal rates. Without predators to thin the small fish populations, such as bluegill, there are too many fish competing for available food resources.

Water quality changes associated with heavy weed growths pose more serious problems. The solar energy trapped in the plant canopy causes a very sharp division of the water column with warm, highly oxygenated water above and cold, poorly-oxygenated water below. The hot layer may be as thin as five or six inches, while the rest of the water column is cold. Neither of these conditions is conducive to the well-

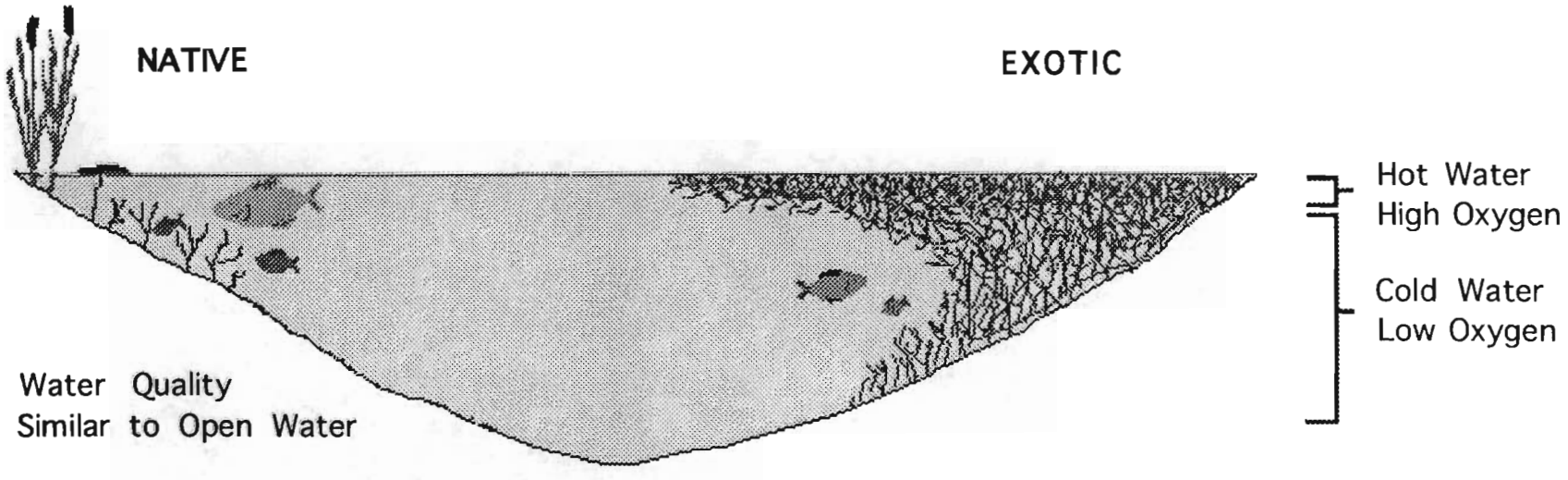
being of most fish and invertebrates. Aquatic animals, therefore, become concentrated at the fringes of the weed mats where exchange with the open water provides tenable conditions. (See page 37 for illustration.) Researchers in Florida examined 60 lakes with weed coverage ranging from zero to near 100 percent to determine the relationship between weed coverage and abundance in sportfish populations (not angler success). They found no correlation.[20]

Research conducted in hydrilla beds in North Carolina measured substantially diminished oxygen levels below the plants, even though the experiments were performed before full canopies could have formed.[21] A Washington State researcher found oxygen levels beneath weed mats to be below the lethal limits for sportfish, but observed no deaths. When he caged largemouth bass and placed them under beds of watershield, an emersed plant, many of the fish died.[22] It is clear that, when lethal conditions occur, fish tend to move to the boundaries of the weed beds, which are areas of better water quality.

Emersed noxious plants also can create poor water quality and diminish fish and wildlife habitat. When the AWCP began work to clear a four-mile long mass of alligatorweed from the upper Pasquotank River, water quality measurements were made in the few patches of open water present in the reach. Oxygen was present in the top half-inch of the water column, but all of the water tested below that level was completely anoxic. The only fishes in that section of the river were mosquitofish, which can skim oxygen from just below the water surface, and bowfin and gar, which are air-breathers.

The alligatorweed in the Pasquotank River was also harming waterfowl feeding. In the two years that the AWCP worked to open the area, no ducks were seen in that stretch of the river. In the first year that the river was clear, however, wood ducks appeared in large numbers, followed in quick succession by wood duck boxes and duck blinds. A similar event occurred three years later when alligatorweed was controlled on the Lumber River.

NATIVE PLANT BED VERSUS EXOTIC PLANT BED



ECONOMIC IMPACTS OF NOXIOUS AQUATIC WEEDS

The kinds of economic impacts caused by some nuisance aquatic plants are shown in Table 5 on page 40. The dollar symbols indicate which impacts have significant costs associated with them. Interference with the withdrawal of surface waters for offstream use is an aquatic plant impact which affects some major sectors of North Carolina's economy from thermoelectric power generation to agriculture. The following table illustrates the proportion of offstream use by major users and the degree to which each user depends upon surface water.

Major Users	Percent of Total Water Use	Degree of Dependence on Surface Water
Thermoelectric Power	85.9	99.9
Public Water Supply	6.8	85.2
Agriculture	1.7	76.6
Industry and Mining	5.5	62.0

Any of these uses can be disrupted by noxious aquatic weeds. Virtually all submersed plants (including the larger algae) have the ability, if enough biomass is present, to clog screens of water intake structures. Hydrilla most often causes damage of this type because large mats break loose from lake bottoms and float around as giant rafts in early winter. Thermoelectric generation facilities are particularly susceptible to loss of cooling water caused by obstructions at intake structures. This vulnerability is particularly important because thermoelectric generation accounts for nearly 90 percent of the power generated in North Carolina.

Disruption of power generated in North Carolina could be disastrous and costly based on experiences of the Tennessee Valley Authority (TVA) and the Corps of Engineers. Two hydropower stations on Guntersville Reservoir in the TVA system and a hydropower station in St. Stephens, South Carolina were shut down by hydrilla in recent years. In Guntersville Reservoir, $170,000 was lost from decreased power generation. In South Carolina, immediate costs of equipment replacement and clean up were $750,000 and $30,000, respectively. Additional repairs have been on-going since 1992 and have cost the Corps an estimated $3-4 million, including costs of lost power generation.[23] Down river from the St. Stephens station, a massive fish kill, valued at $525,000, was also a result of the hydrilla mats. [24]

Table 5. Environmental and Economic Impacts

IMPACTS	NOXIOUS PLANTS			
	Blue-green Algae	**Hydrilla**	**Duckweed**	**Alligatorweed**
Aesthetics	Odoriferous Blooms	Unsightly Mats	Unsightly Mats	Unsightly Mats
Crop Production	No Impact	No Impact	No Impact	Invades Cropland **$$**
Fisheries	Causes Extremes in Oxygen Levels	Limits Access Depletes Oxygen **$$**	Depletes Oxygen	Depletes Oxygen **$$**
Irrigation	Clogs Intake Screens	Impedes Water Flow	Clogs Intake Screens	Flooding **$$**
Navigation	No Impact	Mats Block Waterways **$$**	Mats Inhibit Canoeing Boating	Mats Block Waterways **$$**
Swimming	Causes Skin Irritation	Causes Skin Irritation	Uninviting Mats	Impenetrable Mats
Water Quality	Odoriferous Blooms **$$**	Releases Nitrogen and Phosphorous	Depletes Oxygen	Depletes Oxygen
Water Supply	Clogs Intakes **$$**	Clogs Intakes **$$**	Clogs Intakes **$$**	Clogs Intakes **$$**

Impacts on Agriculture

Invading cropland, interfering with surface water withdrawals, and impeding water flow in irrigation ditches are the major impacts of aquatic weeds on agriculture. Alligatorweed invades cropland, particularly corn, potato and soybean fields. It is estimated that this weed costs North Carolina $170,000 annually. This figure includes chemical application and yield loss.[25] Once it invades a field, terrestrial alligatorweed is difficult to control; no currently labeled herbicides are effective.

Coastal counties that have reported alligatorweed encroaching on cropland are Camden, Currituck, Hyde, Pender, Perquimans, Tyrrell, and Washington. Potential acreage that could be affected by alligatorweed is 17,000 acres of corn worth $4.6 million, 231,000 acres of soybeans worth $28.5 million, and 12,800 acres of potatoes worth $17.8 million.[26] If alligatorweed invades a field, a 25 percent reduction in crop production for corn and a 50 percent reduction for soybeans is not unusual.[27] In one case, a single Hyde County farmer lost $10,000 when alligatorweed invaded his 20 acre corn field and caused a 75 percent reduction in yield.[28] (See photographs on page 43.)

Alligatorweed is also the nuisance species in irrigation canals and drainage ditches in North Carolina. It impedes water flow through ditches and blocks culverts, causing flooding. Alligatorweed is especially prevalent in both Tyrrell and Washington Counties along the Scuppernong River. In 1984, the AWCP began treating this area. Although the original infestations totaled only 15 acres in one section of five canals, 7500 acres of adjacent cropland were affected. Project benefits, which included increased production of corn and soybeans due to better drainage of the area, were compared to the cost of control (including labor, equipment, herbicide) to generate a benefit to cost ratio of almost 7:1.[29] Maintenance treatments continue to control alligatorweed and the area of infestation has been reduced to two acres. This proactive approach to controlling alligatorweed in the canal system protected adjacent cropland, prevented further spread down the river, and reduced risk of damage to downstream cropland.

Impacts on Industry and Municipalities

Both submersed and emersed vegetation interfere with water supply for industries and municipalities. There are 174 municipalities that each withdraw over a million gallons of surface water per day. Municipal water problems also include floating mats of blue-green algae in wastewater treatment plants.

The wastewater treatment plant for the Town of Garner had problems with floating

algal mats clogging screens leading to the chlorination chamber and clogging nozzles in spray fields. Maintenance of this equipment required an annual expenditure of $2,025.[30] The AWCP controlled the algae with 15,000 bighead carp at a cost of $1,539. A benefit cost ratio was calculated to be almost 65:1. Similarly, the lagoon of the wastewater treatment plant at Falls of the Neuse State Park is spending $1750 per year to keep the system operable because of a duckweed infestation.[31] It is unlikely that the system performs as designed. Poor quality wastewater is an environmental cost that is difficult to estimate.

When wastewater treatment plants do not operate properly, the associated impacts are the added economic costs of experimenting with ineffective solutions and the environmental costs of discharging water that does not meet safe standards. Measures can be implemented to control these nuisance plants at high benefit cost ratios. (For photographs of duckweed in aeration pond, see page 44.)

Industries withdrawing water from rivers and lakes experience problems with weeds blocking water supply canals and clogging intake structures. There are over 100 industries that each withdraw more than a million gallons daily. Actual costs of weed problems are difficult to obtain because some industries do not keep specific records; others are reluctant to release this kind of information.

Since 1991, one industrial facility has spent $350,000 on weed problems. This figure includes physical, mechanical, and biological control measures, replacement of equipment, and staff time to analyze the problem. Other industries have moved their intakes to avoid submersed weeds. Associated costs involve pier construction and new equipment, as well as control measures and staff time.

Some public utilities that generate hydroelectric power have environmental programs that include aquatic weed control activities. Both Duke Power Company and Carolina Power and Light (CP&L) have been very effective in managing aquatic weeds in their reservoirs despite reductions in environmental staff due to considerable down-sizing in these companies. Duke Power conducted an in-house economic study and estimated that it avoids costs of $835,000 annually by monitoring and controlling the spread of weeds in their reservoirs.[32] Carolina Power and Light have tilapia stocked in their Lumberton reservoir and are stocking grass carp in Harris Lake.[33]

Impacts on Navigation and Transportation

Navigation is the primary federal concern with regard to aquatic weeds; mats of

Alligatorweed encroaching on a corn field, Tyrrell County

Alligatorweed in Sweetwater Creek, Martin County

Duckweed in aeration pond of a wastewater treatment plant, Roxboro, Person County

Duckweed in Merchant's Millpond, Gates County

Hydrilla in Lake Gaston

Hydrilla in Big Lake, Umstead Park, Wake County

nuisance species can obstruct navigation by creating blockages along rivers and canals. In North Carolina, alligatorweed is the species that affects navigation in rivers and canals, while hydrilla and other submersed species affect navigation in lakes and reservoirs. It has been suggested that if aquatic plant control efforts nationwide were halted, the cost of transportation in inland waters would double.[34] Although there is minimal commercial navigation on North Carolina's inland waterways, there are many recreational boaters that use state rivers and streams. Twenty years ago, estimated losses for small craft navigation were $250,000 due to aquatic weeds; in today's dollars, those losses would be $616,214.[35]

On the Scuppernong River, for instance, the value of recreational boating is $4.16; with alligatorweed impairing navigational use of the river, the value drops to $3.22.[36] Statewide, there are 161 public boat ramps and over 330,000 registered boats. It is obvious that when the economic value of boat ramps declines, there could be significant losses attributable to aquatic weeds. These losses would be manifested both as decreased usage of the water body and water-oriented businesses as well as operational costs for weed management. If the value of a boat ramp in North Carolina declined by $1 per boat launched, and all registered boaters launched an average of three times per year, the economic loss would be $990,000.

Severe flooding can result when alligatorweed mats break loose from the shore and pile up at culverts and bridges during heavy run off. Flooding can wash out nearby roads and bridges. Replacing a medium-sized bridge costs $350,000. The Department of Transportation's Highway Division (DOT) located in the northeastern part of the state controls alligatorweed near bridges, removes mats from bridge supports and along roadside rights-of-way. It is a constant problem that costs between $5000-$6000 annually to physically remove blockages and haul it from the area to burn.[37] Additional costs of spraying herbicides to maintain roadside rights-of-way have increased yearly; almost 80 acres of alligatorweed were treated at a cost of $14,004 in 1995. In 1994, 63 acres were treated at a cost of $16,700 and about 40 acres in 1993 at a cost of $14,000.[38]

Impacts on Recreation

Aquatic weeds block boating ramps, interfere with sportfishing and inhibit swimming. Impacts on boating and associated recreational uses were included in the costs of navigational impacts; recreational sites are inaccessible if aquatic weeds block boat ramps and waterways. (See photographs on page 45.) Sportfishing is closely tied to boating access. There are many direct, indirect, and induced spending effects of angler recreation. In large impoundments, such as Lake Gaston, as many as 30 to 60 anglers

use public boat ramps operated by wildlife agencies of North Carolina and Virginia during the peak season (March through October). [39] On weekends, these figures double. Estimates of direct expenditures range from $44 to $88 per state resident, including lodging, food, travel, and transportation.[40] [41] Using this range, there would be $760,000 to $1.5 million in direct economic benefits annually just from anglers that use public boating ramps alone. Numerous private boat ramps are located around the lake at marinas and on the property of home owners. Real estate and personal property taxes on Lake Gaston contribute $375 million yearly to the local area. [42] Bass fishing tournaments are held around Lake Gaston boat access areas almost every weekend March through October. A recent bass fishing tournament attracted 433 anglers using 216 boats. The total payback for this one tournament was $21,758 which broke all records of Lake Gaston bass tournaments.[43] Using this figure, bass tournaments have the potential to generate almost $700,000 in recreational spending for one season.

Increased recreational spending causes increases in indirect and induced benefits. For example, more money spent on fishing tackle increases demand. Manufacturers need to purchase more raw materials and labor to meet that demand; this spending is an indirect economic benefit. Induced effects are the increased spending on goods and services by the manufacturers and their employees as a result of the extra income generated from increased demand for tackle. Because of indirect and induced benefits, anglers might contribute $3 million to the surrounding counties during one season. If not controlled, aquatic weed infestations can reduce all economic benefits by 90 percent. [44]

On smaller reservoirs, the economic impacts of aquatic weeds on recreation are also significant. Lake Crabtree, for example, is a very popular recreational area in Wake County. An aquatic plant management program was initiated at this site because hydrilla decreased the lake's recreational value. Grass carp in conjunction with some chemical treatments were used to control hydrilla. A benefit to cost ratio for the project was calculated to be almost 9:1. Treatment costs were about $4,700 versus almost $70,000 in recreational benefits annually.

For swimmers, problems arise because both aquatic plants and swimmers use shallow areas near the shore. Not only is swimming nearly impossible, it is unpleasant. Plants are "scratchy" and cause some people to develop skin rashes such as "swimmer's itch." Safety is also a concern. Swimmers may be entangled in the plant biomass and drown. The researcher who was instrumental in confirming the identity of hydrilla in Florida later lost his life entangled in a hydrilla mat while SCUBA diving.[45] Many parks have to clear the swimming areas in their lakes every year. Umstead Park (Wake County) has three lakes, two whose primary recreational value is swimming. There are four

camps located on these lakes. Park rangers have to manually clear hydrilla beds that surround the swimming areas every year. If swimming is undesirable or unavailable, recreational areas, especially campgrounds, will lose revenue. A 1990 estimate for direct spending of one camper daily was $108, including lodging, food, travel, and transportation.[46] At areas with ten sites, the direct economic benefits are about $100,000 for the summer. Indirect and induced benefit increase to $200,000.

NORTH CAROLINA AQUATIC WEED ACTION PLAN

The North Carolina Aquatic Weed Action Plan includes five recommendations to improve North Carolina's ability to meet the challenges posed by the spread of noxious weeds within the State and the threat of new introductions.

1. **Control new weed infestations early to reduce damage and keep costs down.**

   Preventing the establishment of large new weed infestations is the most urgent need in North Carolina. Funding thorough, annual, aquatic plant surveys is the most important element in the early detection of new noxious weed infestations and the key to operating a proactive aquatic plant management program. The Aquatic Weed Control Program would use information gathered from the surveys to assist local governments in early attacks on new infestations. Continued maintenance of existing aquatic weeds would prevent infestations from further spread and would reduce problems for North Carolina agriculture, industry, and recreation.

2. **Find the most cost-effective control methods for weeds.**

   Understanding the biology and distribution of noxious aquatic weeds and investigating the effectiveness of new control methods is essential to controlling weeds at the least possible cost. Agencies and universities that can provide funding for research programs are on the Aquatic Weed Control Council: North Carolina State University, the Water Resources Research Institute, and the North Carolina Agricultural Research Service. Additional resource agencies, such as Sea Grant, and other institutions in the North Carolina University System should be encouraged to provide more opportunities in aquatic plant research. The largest source of funding for aquatic plant research has been eliminated with the budget cuts in the Army Corps of Engineers, Aquatic Weed Control Research Program. Research activities complement an aquatic weed control program.

3. **Develop public support for the prevention and control of weed infestations.**

   No effort to combat the spread of hydrilla or other noxious aquatic weeds will be successful without public understanding and cooperation. Because aquatic weeds are spread by human activities, more information about their harmful impacts needs to be posted in recreational areas. Member agencies of the

Aquatic Weed Control Council should be encouraged to include aquatic weed information when distributing other material on water resources. Additional information could be disseminated to private pond owners through the Cooperative Extension Service. Any and all infestations of hydrilla put public resources at risk.

4. **Eliminate the movement of noxious aquatic weeds into North Carolina by enforcing federal laws and regulations.**

North Carolina is at risk from movements of noxious plants into the state. State authorities should urge the United States Department of Agriculture and the United States Fish and Wildlife Service to enforce the laws that give them jurisdiction over interstate traffic of harmful or noxious species, including aquatic plants. Furthermore, North Carolina should encourage an Aquatic Weed Control Law for other states, especially those that border North Carolina. Currently, South Carolina is the only neighboring state that has a statute in place. A bill has been offered before the Virginia House to amend their noxious weed law to include those plants that are detrimental to surface waters, including lakes. However, Georgia and Tennessee do not regulate aquatic weeds. Unless surrounding states have a laws in place, federal agencies are unlikely to enforce the Federal Noxious Weed Act.

5. **Stop the spread of weed infestations in North Carolina by enforcing the North Carolina Aquatic Weed Control Act and State Noxious Weed Regulations.**

Commercial plant sales and other movement of noxious aquatic weeds in North Carolina result in new infestations. For example, hydrilla was discovered in the ornamental pool at Biltmore Estate (Buncombe County) after fragrant water lilies were purchased and planted in the pool. Many examples of intentional or accidental movement of aquatic weeds into and within the state has been well documented. Continued education of the plant industry is important. Aquatic plant dealers should know which plants are designated as noxious aquatic weeds and understand the penalty for selling them. Additional NCDA Plant Protection Specialists are needed to educate and inspect aquatic plant dealers.

ALTERNATIVE SOURCES OF FUNDING

Existing Sources of Funding Aquatic Weed Control Programs

Taxes, fees, and other revenues are frequently returned to the source of services that generated them. This approach can be applied to increasing funding for aquatic weed control activities. The following are sources of funding for programs in other states:

- a portion of **gasoline tax revenues**

Gasoline is used in motorboats. The States of Florida and South Carolina allocate 1-2 percent of the revenues received from gasoline taxes to support aquatic weed control.

- a portion of **boat registration fees**

Florida also allocates a portion (approximately $1 per boat) of the boat registration receipts to weed control.

- a portion of **boat trailer registration fees**

The State of Washington supports its aquatic weed control program from boat trailer registrations.

Potential Sources of Funding Aquatic Weed Control Programs

The following are sources that could be used for funding aquatic weed control:

- a portion of **highway use tax** because boats are transported on highways

- a portion of **Dingell-Johnson** and **Pittman-Robertson** funds

The Dingell-Johnson and Pittman-Robertson Funds provide aid to state fisheries and wildlife agencies, respectively. The funds are generated by two separate federal taxes on fishing and hunting supplies which are disbursed to the state agencies on the basis of numbers of fishing and hunting licenses. The money is used for research, special investigations, and habitat improvement in both areas. Dingle-Johnson funds support the majority of aquatic weed activities in the State of Alabama.

- **Federal grants**, such as EPA Clean Lakes funds

- **Special tax districts created for weed control**

The State of Michigan created special tax districts surrounding lakes with severe weed problems and levied a graduated tax based upon distance from the lake to be used for weed control. This approach has been successful in Michigan.

Trust Fund

The State of South Carolina has established an Aquatic Plant Control Trust Fund which receives receipts from federal and local cooperators, grants, and gifts from private and public sources. Although legislative appropriations could be placed in the Fund, they go directly to their Aquatic Weed Control Program to support aquatic weed control activities. The Fund provides grants to universities for research on aquatic weed control and funds for special emergency weed control projects. The South Carolina Aquatic Weed Control Council, the model for our North Carolina Council, determines how money from the Trust Fund is spent. If a trust fund for aquatic weed control activities were established in North Carolina, the interest, annual appropriations, and receipts might help assure a constant source of adequate funding for the program.

ENDNOTES

1. Mr. Jeff Schardt, Environmental Administrator, Bureau of Aquatic Plant Management, Florida Department of Environmental Protection, personal communication.

2. J. Schardt and J. Ludlow, 1993. *Florida Aquatic Plant Report: Large Scale Hydrilla Management.* Technical Report 952-CGA, Bureau of Aquatic Plant Management, Florida Department of Environmental Protection, Tallahassee, FL.

3. Mr. Steve de Kozlowski, Water Resources Commission, South Carolina Department of Natural Resources, personal communication.

4. A. Holaday, M. Salvucci, and G. Bowes, 1983. Variable photosynthesis/photorespiration ratios in *Hydrilla* and other submersed aquatic macrophyte species. *Canadian Journal of Botany* 122:229-236.

5. S. Kay, 1992. Publication AG-449, N.C. Cooperative Extension Service, Raleigh, NC.

6. F. Ryan, C. Coley and S. Kay, 1995. Coexistence of monoecious and dioecious hydrilla in Lake Gaston, North Carolina and Virginia. *Journal of Aquatic Plant Management* 33:8-12.

6. S. Kay and A. Poovey, 1995. *Short-term Summer Drawdown as a Potential Tool for Management of Monoecious Hydrilla: Impacts on Hydrilla and Non-target Vegetation.* Bulletin 298, Water Resources Research Institute, University of North Carolina, Raleigh, NC.

8. C. Coley and S. Kay, 1995. Phenological evaluations of hydrilla in North Carolina. *Proceedings,* 35th Annual Meeting of the Aquatic Plant Management Society (abstract only), July 9-12, 1995, Bellevue, WA, p 21.

9. A. Pieterse and K. Murphy, 1993. *Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation.* Oxford University Press, Oxford, U.K., p 72.

10. S. Kay, 1992. Biological control of alligatorweed (*Alternanthera philoxeroides*) in North Carolina. *Proceedings,* 45th Annual Meeting of Southern Weed Science Society (abstract only). January 20-22, Little Rock, AR.

11. G. Davis and M. Brison, 1983. Trends in submersed macrophyte communities of the Currituck Sound:1909-1979. *Journal of Aquatic Plant Management* 21:83-87.

12. Mr. Alton Wood, Jr., Agent for the Currituck County Cooperative Extension Service, personal communication.

13. D. Sutton, 1995. Hygrophila is replacing hydrilla in south Florida. *Aquatics* 17(3):4-10.

14. P. Gosselin, D. Joulain, P. Laurin, and F. Rouessac, 1989. Synthesis of earthy-mouldy smelling compounds-I. stereoselective synthesis of (±) geosmin. *Tetrahedron Lett.* 30:2775-2778.

15. P. Persson, 1984. Uptake and release of environmentally occurring odorous compounds by fish. *Water Resources* 18(10):1263-1271.

16. S. Moikeha, G. Chu, and L. Berger, 1971. Dermatitis-producing alga *Lyngbia majuscula* Gomont in Hawaii. II, Biological properties of the toxic factor. *Journal of Phycology* 7:8-13.

17. H. Fujiki, M. Suganuma, H. Hakii, G. Bartolini, R. Moore, S. Takayama, and T. Sugimura, 1984. A two-stage mouse skin carcinogenesis study of lyngbyatoxin. *American Journal of Cancer Research and Clinical Oncology* 108:174-176.

18. Y. Kato and P. Scheuer, 1974. The aplysiatoxins. *Pure Applied Chemistry* 41:1-14.

19. Y. Kato and P. Scheuer, 1976. The aplysiatoxins: reactions with acid and oxidants. *Pure Applied Chemistry* 48:29-33.

20. D. Canfield and M. Hoyer, 1992, "Aquatic Macrophytes and Their Relation to the Limnology of Florida Lakes." Final report to Bureau of Aquatic Plant Management, Florida Department of Environmental Protection, Tallahassee, FL.

21. G. Pesacreta, 1988. "Water Chemistry from North Carolina Piedmont Impoundments with Hydrilla (*Hydrilla verticillata* (L.f.)Royle) ." Ph.D. dissertation, North Carolina State University, Raleigh, NC.

22. G. Pauley, G. Thomas, S. Bonar, J. Frodge, D. Marino, S. Thiesfield, S. Vecht, K. Bowers, and H. Sehgal, 1994. An overview of the use and efficacy of triploid

grass carp *Ctenopharyngodon idella* as a biological control of aquatic macrophytes in Oregon and Washington state lakes. *Proceedings*, Grass Carp Symposium, March 7-9, 1994, Gainesville FL., pp 46-54.

23. Mr. Jerry McSwain, U.S. Army Corps of Engineers, St. Stephens, SC, personal communication.

24. Mr. Steve de Kozlowski, Water Resources Commission, South Carolina Department of Natural Resources, personal communication.

25. Dr. Alan York, Professor, Crop Science Department, North Carolina State University, personal communication.

26. North Carolina Department of Agriculture, statistics published at http://www.agr.state.nc.us.../price_rec/prrcanyr.html

27. Mr. Lewis Smith, Agent for the Perquimans County Cooperative Extension Service, personal communication.

28. Mr. Mac Gibbs, Agent for the Hyde County Cooperative Extension Service, personal communication.

29. U.S. Army Corps of Engineers, 1986. *Supplemental Information for Environmental Assessment: Alligatorweed Control.* Wilmington District, Wilmington, NC.

30. Mr. Tim Woody, Plant Supervisor, Town of Garner Wastewater Treatment Plant, personal communication.

31. Ms. Jane Bernard, Plant Supervisor, Falls Lake Wastewater Treatment Plant, personal communication.

32. M. Bailey, 1995, "Economic Benefits of Aquatic Plant Control at Duke Power Company." Presentation given at 17th Annual Meeting, South Carolina Aquatic Plant Management Society, October 4-6, Myrtle Beach, SC.

33. Mr. Mike Swing, District Biologist, Carolina Power & Light, personal communication.

34. E.O. Gangstad, 1978. *Weed Control Methods for River Basin Management.* CRC Press, West Palm Beach, FL, pp 83-85.

35. E.O. Gangstad, 1978. *Weed Control Methods for River Basin Management.* CRC Press, West Palm Beach, FL, pp 83-85.

36. U.S. Army Corps of Engineers, 1984. *Environmental Assessment: Alligatorweed Control.* Wilmington District, Wilmington, NC.

37. Mr. Billy Leggett, Engineer, District 3, I Division, DOT, personal communication.

38. Mr. J. Benton, Supervisor of Roadside Environmental Planning, District 3, I Division, DOT, personal communication.

39. Mr. Bud LaRoche, Regional Fisheries Supervisor, Virginia Department of Game and Inland Fisheries, personal communication.

40. J. Henderson, 1995. Use of economic information in the evaluation of aquatic plant control programs. *Proceedings, 29th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-95-3, U.S. Army Corps of Engineer Waterways Experiment Station, Vicksburg, MS, pp 8-18.

41. J. Milon and R. Welsh, 1989. *An Economic Analysis of Sport Fishing and the Effects of Hydrilla Management in Lake County, Florida.* Economics Report 118, Institute of Food and Agriculture, University of Florida, Gainesville, FL.

42. $375,000,000 yearly added to local taxes and businesses by lake property owners, *The Lake Gaston Gazette*, November 2, 1993, vol 1, no 1, p 1.

43. Ms. Joan Holmes, 1996. Red man tournament breaks record. *The Lake Gaston Gazette*, April 9, vol 4, no 15., p 7-B.

44. D. Colle, J. Shireman, W. Haller, 1987. Influence of hydrilla on harvestable sport-fish populations, angler use, and angler expenditures at Orange Lake, Florida. *North American Journal of Fisheries Management* 7:410-417.

45. J. Schardt and D. Schmitz, 1990. *Florida Aquatic Plant Report: Large Scale Hydrilla Management.* Technical Report 90-CGA, Bureau of Aquatic Plant Management, Florida Department of Environmental Protection, Tallahassee, FL.

46. J. Henderson, 1995. Use of economic information in the evaluation of aquatic plant control programs. *Proceedings, 29th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-95-3, pp 8-18.

APPENDIX

HOUSE BILL 230, SECTION 26, STATEWIDE AQUATIC WEED ASSESSMENT RATIFIED JULY 28, 1995

Requested by: Representatives Wilkins, Mitchell, Weatherly, H. Hunter, Senator Martin of Pitt

STATEWIDE AQUATIC WEED ASSESSMENT

Sec. 26.(a) Of the funds appropriated in this act to the Department of Environment, Health, and Natural Resources, the sum of thirty thousand dollars ($30,000) for the 1995-96 fiscal year shall be used by the Department of Environment, Health, and Natural Resources and the North Carolina Aquatic Weed Council to study aquatic weed infestation on a statewide basis.

(b) The Department of Environment, Health, and Natural Resources and the North Carolina Aquatic Weed Council shall report their findings to the Joint Legislative Commission on Governmental Operations by March 15, 1996.

(c) The report shall identify relevant research related to the control and eradication of noxious aquatic plants, include an assessment of the environmental and economic impacts caused by infestation, an assessment of the impact of federal regulations, and a discussion of the issues and options related to control and eradication, enforcement and funding mechanisms. The report shall also include options to reduce or eliminate aquatic weed infestation and a recommended statewide action plan. The report shall consider funding issues and shall address both total budgetary requirements and alternative sources of funding, including fees and other receipts.

§113A-225. Responsibilities of other State agencies.

All State agencies shall cooperate with the Secretary to assist in the implementation of this Article.

§113A-226. Enforcement.

(a) Any person who violates this Article or any rule adopted pursuant to this Article shall be guilty of a misdemeanor and, upon conviction, shall be fined not less than fifty dollars ($50.00) or more than one thousand dollars ($1000), or imprisoned for not less than 10 days nor more than 180 days, or both, for each offense.

(b) Whenever there exists reasonable cause to believe that any person has violated this Article or rules adopted pursuant to this Article, the Secretary may request the Attorney General to institute a civil action for injunctive relief to restrain the violation. The Attorney General may institute such action in the name of the State upon relation of the Department in the superior court of the county in which the violation occurred. Upon a determination by the court that the alleged violation of the provisions of this Article or of rules adopted pursuant to this Article has occurred or is threatened, the court shall grant the relief necessary to prevent or abate the violation or threatened violation. Neither the institution of the action, nor any of the proceedings thereon shall relieve any party to such proceedings from any penalty otherwise prescribed for violations of this Article.

§113A-227. Adoption of rules.

The Secretary may adopt rules necessary to implement the provisions of this Article pursuant to Chapter 150B of the General Statutes.

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Aquatic Weed Control Act of 1991

(Article 15, Chapter 113A of the General Statutes of North Carolina)

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AQUATIC WEED CONTROL ACT OF 1991
ARTICLE 15, CHAPTER 113A

GENERAL STATUTES OF NORTH CAROLINA

Article 15. Aquatic Weed Control

§113A-220. Short title.

This Article shall be known as the Aquatic Weed Control Act of 1991.

§113A-221. Definitions.

Unless a different meaning is required by the context, the following definitions shall apply throughout this Article:

(1) "Department" means the Department of Environment, Health, and Natural Resources.

(2) "Secretary" means the Secretary of Environment, Health, and Natural Resources or his designee.

(3) "Noxious aquatic weed" means any plant organism so designated under this Article.

(4) "Waters of the State" means any surface body or accumulation of water, whether publicly or privately owned and whether naturally occurring or artificially created, which is contained within, flows through, or borders upon any part of this State.

§113A-222. Designation of noxious aquatic weeds.

(a) The Secretary, after consultation with the Director of the North Carolina Agricultural Extension Service, the Wildlife Resources Commission, and the Marine Fisheries Commission, and with the concurrence of the Commissioner of Agriculture, may designate as a noxious aquatic weed any plant organism which:

(1) Grows in or is closely associated with the aquatic environment, whether floating, emersed, submersed, or ditch-bank species, and including terrestrial phases of any such plant organism;

(2) Exhibits characteristics of obstructive nature and either massive productivity or choking density; and

(3) Is or may become a threat to public health or safety or to existing or new beneficial uses of the waters of the State.

(b) A plant organism may be designated as being a noxious aquatic weed either throughout the State or within specified areas within the State.

(c) The Secretary shall designate a plant organism as a noxious aquatic weed by rules adopted pursuant to Chapter 150B of the General Statutes.

(d) The Secretary may modify or withdraw any designation of a plant organism as a noxious aquatic weed made previously under this section. Any modification or withdrawal of such designation shall be made following the procedures for designation set out in this section.

§113A-223. Powers and duties of the Secretary.

(a) The Secretary shall direct the control, eradication, and regulation of noxious aquatic weeds so as to protect and preserve human health, safety, and the beneficial uses of the waters of the State and to prevent injury to property and beneficial plant and animal life. The Secretary shall have the power to :

(1) Conduct research and planning related to the control of noxious aquatic weeds;

(2) Coordinate activities of all public bodies, authorities, agencies, and units of local government in the control and eradication of noxious aquatic weeds;

(3) Delegate to any public body, authority, agency, or unit of local government any power or duty under this Article, except that the Secretary may not delegate the designation of noxious aquatic weeds;

(4) Accept donations, grants, and services from both public and private sources;

(5) Enter into contracts or agreements, including cost-sharing agreements, with public or private agencies for research and development of methods of control of noxious aquatic weeds or for the performance of noxious aquatic weed control activities;

(6) Construct, acquire, operate, and maintain facilities and equipment necessary for the control of noxious aquatic weeds; and

(7) Enter upon private property for purposes of conducting investigations and engaging in aquatic weed control activities.

(b) The Secretary may control, remove, or destroy any noxious aquatic weed located in the waters of the State or in areas adjacent to such waters wherever such weeds threaten to invade such waters. The Secretary may employ any appropriate control technology which is consistent with federal and State law, regulations, and rules. Control technologies may include, but are not limited to drawdown of waters, application of chemicals to shoreline and surface waters, mechanical controls, physical removal from transport mechanisms, quarantine of transport mechanisms, and biological controls. Any biological control technology may be implemented only after the environmental review provisions of the State Environmental Policy Act have been satisfied.

(c) In determining the appropriate strategies and technologies, the Secretary shall consider their relative short-term and long-term cost-efficiency and effectiveness, consistent with a margin of safety adequate to protect public health and the resources of the State.

(d) All activities carried out by the Secretary, his designees, and others authorized to perform any function under this Article shall be consistent with all applicable federal and State law, regulations, and rules.

§113A-224. Powers of the Commissioner of Agriculture.

(a) The Commissioner of Agriculture may regulate the importation, sale, use, culture, collection, transportation, and distribution of a noxious aquatic weed as a plant pest under Article 36 of Chapter 106 of the General Statutes.

(b) This Article shall not be construed to limit any power of the Commissioner of Agriculture, the Department of Agriculture, or the Board of Agriculture under any other provision of law.

Table 1. Noxious Aquatic Weed List

Aquatic Species Listed on the Federal Noxious Weed List

Azolla pinnata R. Brown - Pinnate mosquitofern
Eichhornia azurea (Sw.) Kunth - Anchored waterhyacinth
Hydrilla verticillata (L.f.) Royle - Hydrilla
Hygrophila polysperma (Roxb.)T. Anderson - Indian hygrophila
Ipomoea aquatica Forsk. - Swamp morning glory, water spinach
Lagarosiphon major (Ridley) Moss - African elodea
Limnophila sessiflora (Vahl) Blume - Limnophila
Melaleuca quinquernervia (Cav.) Blake - Melaleuca
Monochoria hastata (L.) Solms - Arrowleaved monochoria
Monochoria vaginalis (Burm. f.) Kunth - Monochoria
Sagittaria sagittifolia L. - Arrowhead
Salvinia auriculata Aubl. - Giant salvinia
Salvinia bioba Raddi - Giant salvinia
Salvinia herzogii de la Sota - Giant salvinia
Salvinia molesta Mitch. - Giant salvinia
Sparganium erectum L. - Branched burreed
Stratiotes aloides L. - Crab's claw

Additional Noxious Aquatic Weeds

Crassula helmsii - Swamp stonecrop
Lagarosiphon spp. (All species) - African elodea
Salvinia spp. (All except S. rotundifolia) - Water fern
Trapa spp. (All species) - Water chesnut
Ludwigia uruguayensis (Camb.) Hara - Uruguay waterprimrose
Lythrum salicaria L. - Purple loosestrife
Phragmites australis (Cav.) Trin. Ex Steud. - Common reed
Alternanthera philoxeroides (Martius) Grisebach - Alligatorweed
Egeria densa Planch. - Brazilian elodea
Myriophyllum spicatum L. - Eurasian watermilfoil
Najas minor All. - Brittleleaf naiad

Table 2. Members of the Interagency Aquatic Weed Control Council

FEDERAL AGENCIES

U.S. Fish and Wildlife Service
U.S. Natural Resources Conservation Service
U.S. Department of Agriculture
APHIS Methods Development Center
U.S. Army Corps of Engineers

STATE AGENCIES

N.C. Cooperative Extension Service
N.C. Department of Agriculture
N.C. Department of Environment, Health, and Natural Resources:
Division of Water Resources
Division of Coastal Management
Division of Environmental Health
Division of Environmental Management
Division of Land Resources
Division of Marine Fisheries
Division of Parks and Recreation
Wildlife Resources Commission

INDUSTRY

ElfAto Chem North America, Inc.

ACADEMIC INSTITUTIONS

North Carolina State University
Crop Science Department
Fisheries and Wildlife Science Program

MUNICIPALITIES

City of Raleigh Department of Utilities

PUBLIC UTILITIES

Duke Power Company
Carolina Power & Light
Virginia Power/North Carolina Power Company

HOW TO APPLY

Local governments are invited to apply for inclusion in the North Carolina Aquatic Weed Control Program. Government units seeking assistance should contact program representatives at the following address:

Aquatic Weed Control Program
EHNR-Water Resources
P.O. Box 27687
Raleigh, NC 27611
(919) 733-4064

- Requests received by September 30 each year will be considered for inclusion in the work plan of the following summer.
- A telephone call or letter may serve as the initial communication. Be prepared to describe the problem in detail.
- A site visit by the Division of Water Resources will determine eligibility for the program.
- A resolution approved and signed by the local board or council will serve as the official application for assistance. A sample resolution will be sent upon request.
- Notification of inclusion will be in early spring.

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State of North Carolina
Division of Water Resources
Department of Environment, Health, and Natural Resources.

James G. Martin, Governor
William W. Cobey, Jr., Secretary

North Carolina Department of Environment, Health, and Natural Resources
Division of Water Resources
P.O. Box 27687
Raleigh, North Carolina 27611

Swamped by Aquatic Weed Problems?

We may be able to help...

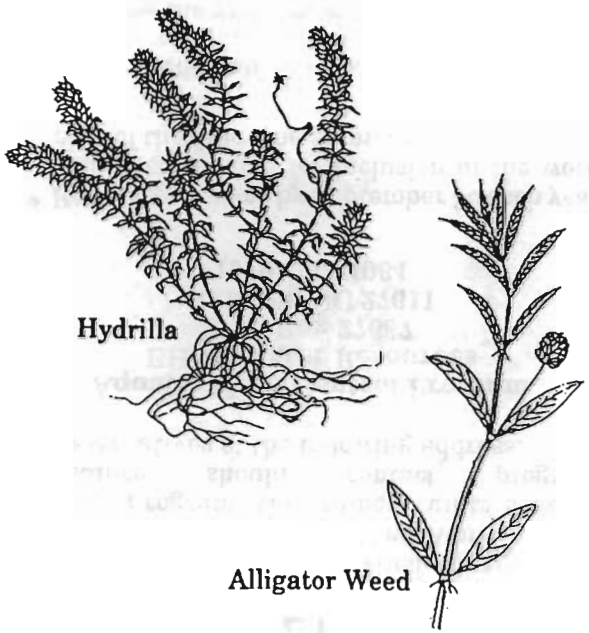
North Carolina Aquatic Weed Control Program

Division Of Water Resources
Department of Environment, Health, and Natural Resources

Most Aquatic Plants Serve Useful Purposes, But Some Grow Out Of Control And Become Weeds.

WATER WEEDS:

- form dense beds in water which make swimming, fishing, boating, and waterskiing difficult and dangerous;
- clog water intake systems of industries, municipalities and irrigators;
- provide breeding habitat for mosquitoes and other pests;
- impede water flow in irrigation and drainage canals which may cause flooding;
- are difficult and expensive to control.



THE PROGRAM

The NC Division of Water Resources assists local governments by providing free evaluation of aquatic weed problems affecting public waters and cost-sharing when control efforts are needed.

The Division is equipped and staffed to handle most aquatic weed problems.

Early attention to developing problems reduces both the damage caused by weeds and the cost of controlling them.

ELIGIBILITY

North Carolina local government units eligible for assistance under the program include:
Municipalities
Counties
Soil and Water Conservation Districts
(Private landowners with aquatic weed problems should contact the county offices of the Agricultural Extension Service for assistance).

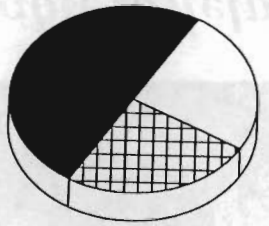
Approval of applications is competitive, based on project benefits, and limited by the amount of State and Federal funds available.

Two cost-sharing formulas are available.

COST-SHARING FORMULAS

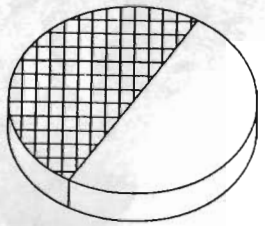
I. Projects with federal assistance through the US Army Corps of Engineers and the State share costs as follows:

Federal	**50%**
State	**25%**
Local	**25%**



II. Projects not qualifying for federal assistance may receive financial aid from the State with costs shared as follows:

State	**50%**
Local	**50%**



CONTROL METHODS

Physical: Water level manipulation, deepening near-shore areas, use of dyes or bottom covers.

Mechanical: Removal of weeds with hand tools or mechanical equipment.

Biological: Use of weed-eating fish or insects and diseases which attack weeds.

Chemical: Use of herbicides approved by the US Environmental Protection Agency for aquatic use.

NORTH CAROLINA HYDRILLA INFESTATIONS AS OF 1995

SITE	SIZE (acres)	INFESTATION (acres)
WAKE CO.		
HARRIS LAKE	4,000	1,200
LAKE WHEELER	542	200
LAKE CRABTREE	500	10
LAKE BENSON	500	200
BRIER CREEK RES.	160	48
LAKE JOHNSON	145	29
LAKE LOCHMERE	100	30
PAGE LAKE	75	50
LAKE RALEIGH	63	20
BIG LAKE	60	27
LAKE LYNN	56	22
SHELLY LAKE	53	14
FRED BOND	45	25
RICHLAND CREEK	45	10
SORRELL'S GROVE	29	0
REEDY CREEK LAKE	22	13
DUNAQAY'S POND	21	13
YATES MILL POND	20	1
SYCAMORE LAKE	20	11
LAKE ANNE	16	2
OXFORD HUNT POND	10	4
CAMP DURANT	8	2
BELLE MEADE EST	7	3
EDGEHILL FARM PD	7	3
CARQUEST POND	6	1
WHEELER 1010 POND	6	6
LOWER WALDEN MNR	6	1
UPCHURCH POND	6	Trace
PEARCE POND	5	2
DORTHEA DIX 2	5	Trace
PATE POND	5	2
TRIANGLE SWIM CLUB	5	3
WEAVER'S POND	4	2
BRIERWOOD POND	3	1
DORTHEA DIX 1	3	Trace
BENSON POND	3	3
DELTA LAKE	3	2
LITTLE DAY POND	3	1
MILBROOK RD POND	2	1
DAY POND	2	1
BRIDGES LAKE	2	1
LAMSHIRE POND	2	1
PLEASANT VALLEY	1	1
CEMETARY POND	1	1
GLOBE RD POND	1	1
GRAYBEAL POND	1	Trace
CANTERBURY WOODS	3	1
BANKS KERR POND	1	1
UPPER WALDEN MNR	1	Trace
AIRPORT POND	1	1
GRANVILLE		
HOLT RESORT	327	50
LAKE ROGERS	141	76
LEDGE CREEK	Creek	1
LAKE DEVIN	125	1
KNAPS OF REEDS	20	1
JACK KEY'S POND	8	4
NEW HANOVER		
BURNT MILL POND	21	21
BURNT MILL CK	20	1
NCCES-WILMINGTON	4	Trace
WRIGHTSVILLE BCH	Tiny pond	Trace

SITE	SIZE (acres)	INFESTATION (acres)
RANDOLPH		
KENNEDY POND	2	2
WALL POND	1	1
OLD WHEATMORE	25	8
RANDEL HILL POND	11	1
PERSON		
HYCO RESORT	4,300	30
MAYO RESORT	2,800	1
NORTHAMPTON		
WASHBURN-GASTON	2	1
ROANOKE RIVER HWY 48	River	1
HALIFAX		
LAKE GASTON	20,300	3,102
ROANOKE RAPIDS LK	4,900	100
DURHAM		
TWIN LAKES 1	8	1
TWIN LAKES 2	7	3
VANCE		
KERR LAKE	49,000	10
ORANGE		
ORANGE LAKE	155	89
NASH		
BIGGERSTAFF POND	2	1
MOORE		
WOOD LAKE	1,000	875
JOHNSON		
JIM WILLIAMS POND	2	1
HERTFORD		
CATHERINE CREEK	Creek	2
CUMBERLAND		
ARRON LAKE	50	40
BUNCOMBE		
BILTMORE ESTATES	Tiny pond	Trace
FRANKLIN		
DARIES BIGGERSTAFF	3	1

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