

Aquatics

JUNE 1984



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EDITORIAL

Unfortunately, most important economical issues as well as environmental issues are driven and controlled mostly by politics. To say that surface water, wetlands and ground water concerns are politically hot is similar to calling Lake Okeechobee a good sized pond. In the past, we in Florida have had our share of controversy deciding what agency is responsible for directing aquatic weed control activities. Finally the E.P.A., Florida Dept. of Agriculture, Fla. D.E.R., H.R.S., Fla. Game & Freshwater Fish Commission, DNR, State universities, water management districts and even fish camp owners came to the American Assembly Conference in 1979. They structured an aquatic weed management lead agency to end the battle between DNR and the Fla. Game and Fish Commission. The solution consisted of DNR being the lead agency and would control permitting and funding of aquatic plant weed activities. None of DNR's trust fund was to go to the Commission. The Fla. GFC would be out of the aquatic weed business except in dealing in biological agents. Resolved — right? Wrong.

Each year since then the Game Commission mysteriously receives a very substantial portion of DNR's trust fund budget. It started with approximately \$300,000 and now has grown to \$400,000. DNR does **not** make the transfer voluntarily nor does the Game Commission reportedly "seek" the funding. How and why does the transfer happen? Legend has it that a "good fairy" is on the Governor's staff and makes this annual delivery. Why?

If the Game Commission desires to work with new exotic fish each year and use DNR money on a dual permitting system then they should use their own funds, not DNR's aquatic weed trust fund money which is needed for weed control.

Aquatic managers in Florida are often referred to as rabble rousers — because many are. Maybe we just want things done right and above board in order that the public be properly served.

Aquatics

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Summertime is here. Water recreation is the way to go on Lake Hall, McClay Garden in Tallahassee. Photo by David P. Tarver

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AQUATICS: Published quarterly as the official publication of the Florida Aquatic Plant Management Society. This publication is intended to keep all interests informed on matters as they relate to aquatic plant management, particularly in Florida.

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Spikerushes

by
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The spikerushes, genus *Eleocharis*, are included in the Cyperaceae or Sedge family. This is a large family of plants composed of 83 different genera with about 3,200 species distributed throughout the world. They are particularly abundant in the subarctic and temperate regions of both the northern and southern hemispheres. These plants are found in damp, boggy, marshy, or riparian habitats.

The Sedge family is characterized as fibrous-rooted grasslike herbs with very minute flowers subtended by chaffy bracts. These bracts are specialized leaves and the flowers arise from their axils. The stems, also commonly called culms, are mostly solid, often triangular, generally unbranched below the inflorescence (flower), and frequently leafless.

The spikerushes are separated from the other members of the Sedge family by the formation of a solitary terminal spikelet without obvious subtending bracts, hence the name spikerush. In some species the spike is thicker than the

supporting stem below it while in others the spike is not distinctly thicker than the stem.

Physical aspects of the achenes (small dry indehiscent fruit with a relatively thin wall surrounding a single seed) are used to separate the species (Figure 1). The genus is also characteristically without leaves so that the culm carries on the photosynthetic activities of the plant.

The genus name *Eleocharis* is derived from the Greek 'hele' or 'helos' for marsh and 'charis' for grace as described by Robert Brown in 1810 (7). The name is actually closer to the Greek 'helodes' for marshy and 'charisma' for favor or gift.

At times this genus has also been called *Heleocharis*. This spelling has been rejected by most taxonomists but may occasionally appear in the literature. The species may also be called by the common name of hairgrass.

Some confusion exists in the literature as to the identification of the various spikerush species. In 1929 Svenson (7) separated the genus into 11 series each representing a natural group. Each group contained very similar appearing plants, and the grouping still provides a useful starting point for the identification of the spikerushes.

The species are difficult to identify because of their simple gross anatomical structure which consists primarily of a modified stem, the culm. The achenes must be examined for positive species identification, however they are so small that they must be examined microscopically to distinguish their characteristic markings.

Long and Lakela (3) list seven species occurring in south Florida, and Godfrey and Wooten (1) list 33 species present in the southeastern United States of which 29 are listed for Florida.

Those spikerushes which are listed as occurring in the Panhandle of Florida include *Eleocharis interstincta* (Vahl) R. & S.; *Eleocharis*

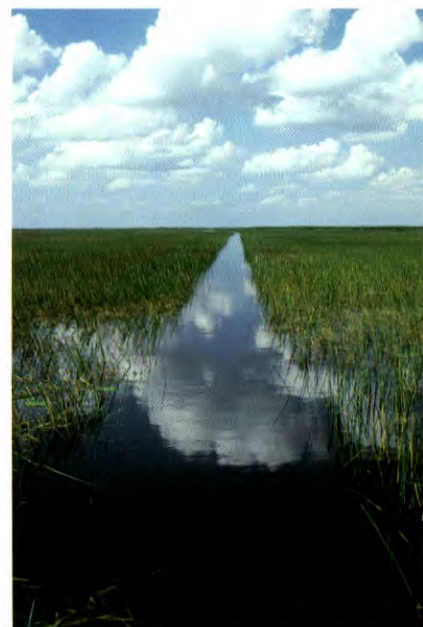


Figure 2. An airboat trail cuts through an extensive stand of *Eleocharis cellulosa* in Lake Okeechobee.

robbinsii Oakes; *Eleocharis radicans* (A. Dietr.) Kunth; *Eleocharis acicularis* (L.) R. & S.; *Eleocharis obtusa* (Willd.) Schultes in R. & S.; *Eleocharis olivacea* Torr.; and *Eleocharis tortilis* (Link) Schultes in R. & S. Those found throughout Florida include *Eleocharis quadrangulata* (Michx.) R. & S.; *Eleocharis elongata* Chapm.; *Eleocharis cellulosa* Torr.; *Eleocharis montana* (HBK.) R. & S.; *Eleocharis flavescens* (Poir.) Urban; *Eleocharis geniculata* (L.) R. & S.; *Eleocharis atropurpurea* (Retz.) Kunth; *Eleocharis fallax* Weath.; *Eleocharis baldwinii* (Torr.) Chapm.; *Eleocharis parvula* (R. & S.) Link; *Eleocharis rostellata* Torr.; *Eleocharis nigrescens* (Nees) Steud.; *Eleocharis melanocarpa* Torr.; *Eleocharis minima* Kunth; *Eleocharis microcarpa* Torr.; and *Eleocharis albida* Torr.; *Eleocharis montevidensis* Kunth; and *Eleocharis vivipara* Link. A few species such as *Eleocharis equisetoides* (Ell.) Torr.; *Eleocharis tuberculosa* (Michx.) R. & S.; and *Eleocharis nana* Kunth are found primarily in the central to the northern portion of the state. *Eleocharis tricostrata* Torr. is found in north Florida.

In south Florida *E. microcarpa* is present in the Fisheating Creek area near Lake Okeechobee, and *E. baldwinii* is found in many canals. Both of these plants grow submersed and may be confused with some of the small-leaved pondweeds or naiads.

During the 1982 survey for
continued on page 9



Figure 1. Spike of *Eleocharis geniculata* with flowers and achenes. The distance between each bar is 1.0 mm.

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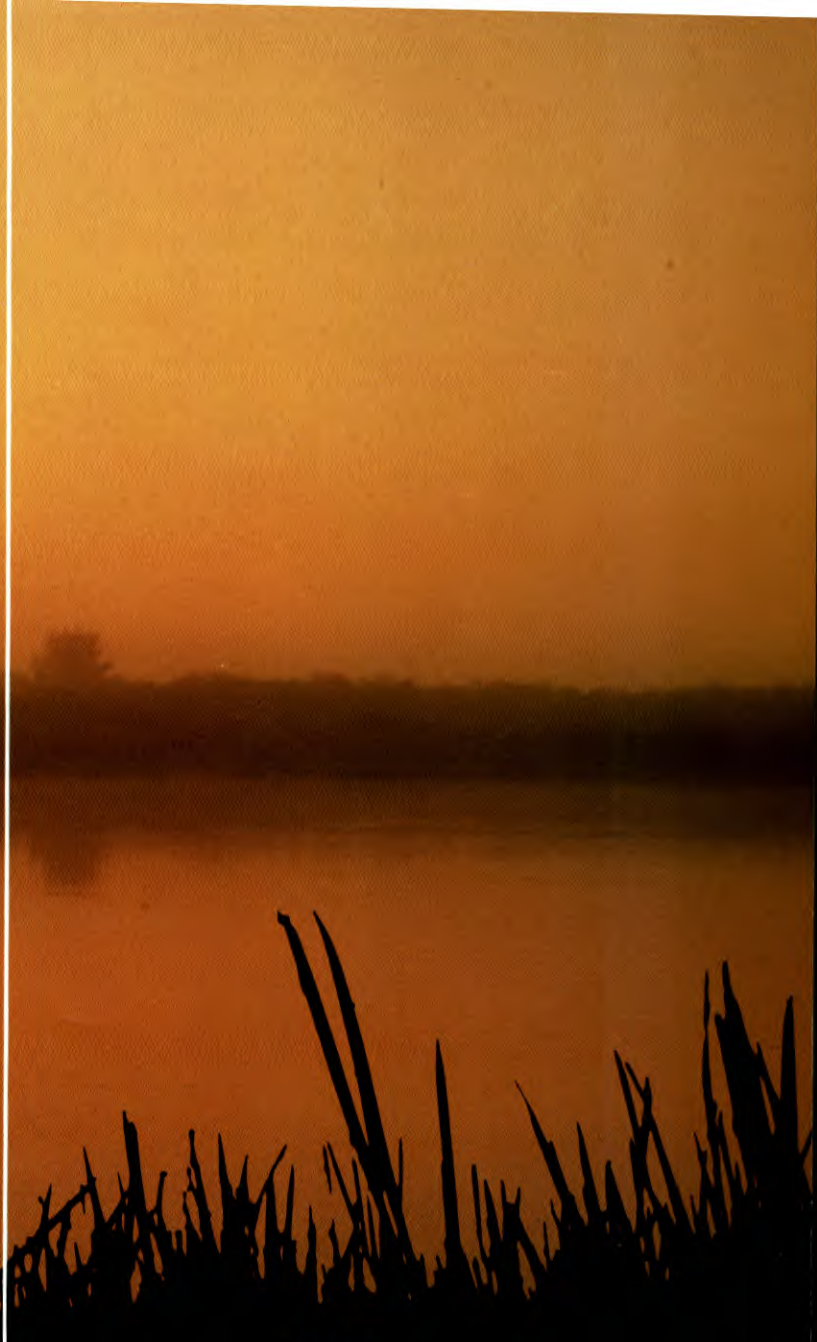
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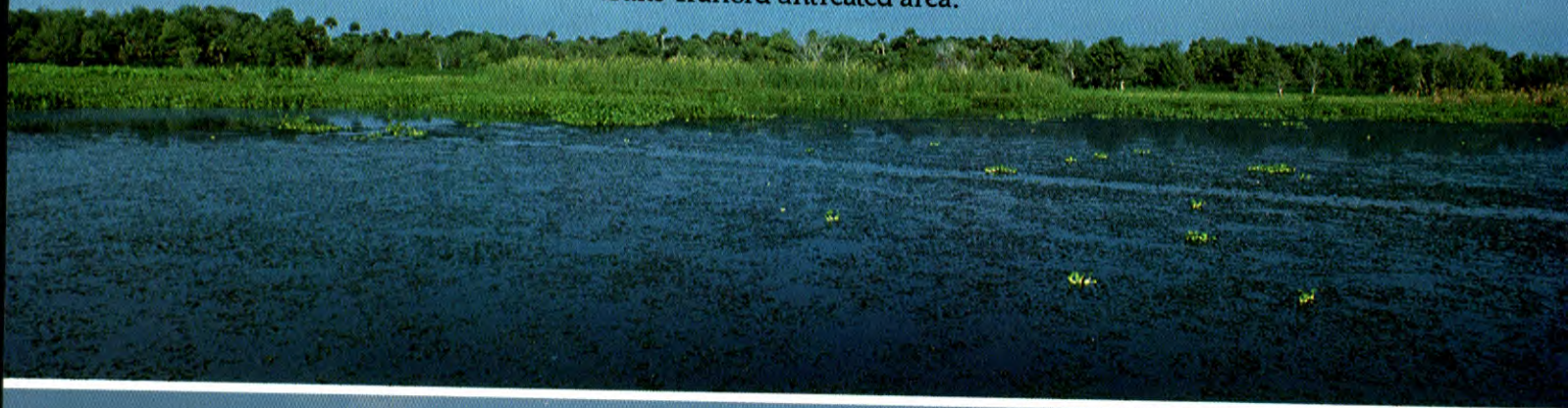
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continued from page 4

aquatic plants in Florida (5), over 1,200 acres in Lake Okeechobee were reported to be covered with *E. cellulosa* (Figure 2). Another similar appearing species but with distinctive partitions in the culm which give it a bamboo-like appearance is *E. interstincta*. This plant was found in over 2,500 acres in Lake Okeechobee and ranked as the 19th most abundant aquatic plant in the survey.

Eleocharis geniculata is considered a tropical plant, but has been reported as far north as South Carolina. This plant is usually not strictly aquatic but occurs along ditchbanks and the shoreline areas of many bodies of water. It will also grow submersed.

Eleocharis acicularis is listed along with 20 other species as having the most extensive range of all aquatic plants throughout the world (6). In North America, *E. palustris* is probably the most widespread of the spikerushes (4).

The spikerushes grow marginally, emersed, or submersed but the culm must be emersed for flowering to occur. Their flowers contain both stamens and pistils. Some of the spikerush species are pollinated by the wind (6), while others, since they have both stamens and pistils on the same flower may be self-pollinating.

Seeds of the spikerushes exhibit prolonged dormancy which is characteristic of many aquatic angiosperms. The mature seeds are normally enclosed by air within one or more associated bracts and float freely until they become waterlogged (6).

Yeo and Dow (9) found that dormancy in dwarf spikerush

[*Eleocharis coloradoensis* (Britt.) Gilly] was broken by chilling the seeds at 2 C for 3 months followed by soaking them for 10 hours in a 5.25% sodium hypochlorite solution. Also, seeds of this species were found to survive extremely hot (72 C) and cold (-196 C) temperatures (10).

Little published information is available on the life cycles of the spikerushes. Some of the species are annual and others are perennial. Some spread by seed, while others produce new shoots vegetatively after a seedling has become established.



Figure 4. Some of the spikerushes form tuft-like growth similar to that of *Eleocharis geniculata*.

Morphology of the spikerushes is varied. Some species are short in stature and form a turf-like growth as exemplified by *E. acicularis* in Figure 3. These types may be found on lake bottoms, in shallow water, or on muddy shores. Other species such as *E. geniculata* are tall, clumped, and tufted (Figure 4).

At first glance, the spikerushes can be mistaken for terrestrial plants when they are growing in ditches (Figure 5) and drained shoreline areas. Under these conditions they may be surrounded by non-aquatic plants such as grasses and other plants which cannot tolerate submersed conditions for extended periods of time.

Some spikerushes are important for their thick root system which helps stabilize the hydrosol against wave action and erosion. Many of the spikerushes provide food for waterfowl (4). Also, the dense growth of these plants provides excellent cover for a myriad of aquatic organisms.

A new interest in the spikerushes

has been stimulated because of their potential use in pollution abatement and aquatic weed management.

In central Pennsylvania, *E. acicularis*, because it is acid tolerant, appears to be ideally suited both functionally and structurally for renovation of mine-acid polluted streams (2). In this situation the spikerush serves as a primary producer and helps stabilize alluvial sediment.

Several of the short, "turf-like" spikerushes attain a rather uniform height. Growth of such plants in the lower portion of the water column would be more desirable than other plants such as hydrilla [*Hydrilla verticillata* (L.f.) Royle] which can fill the entire column.

In California, dwarf spikerush grows well in the Corning canal near Red Bluff (8). A combination of herbicides and drawdown seems to encourage growth of the dwarf spikerush but retards growth of several pondweeds (*Potamogeton* spp.) and elodea (*Elodea canadensis* Michx.). The advantage in this case is that water flow is not impeded as much by the spikerush as by the dense growth of pondweeds and elodea.



Figure 5. Growth of several spikerushes in a ditch near La Belle, Fl.

The spikerushes are normally not thought of as weeds. In the 1982 aquatic plant survey for Florida (5), only two bodies of water were found to contain moderate infestations of unidentified spikerushes.

Most of the problems with spikerush occur in small enclosed bodies of water. At times however, they can grow in such abundance that floating mats cause problems with



Figure 3. Turf-like growth of some of the spikerushes is exemplified by *Eleocharis acicularis*.

water flow, navigation, and general water use.

In south Florida spikerushes may be seen growing along the edges and shallow water areas of canals when submersed weeds are controlled. Under these conditions the spikerushes are generally not considered as problems.

Little information is available on the control of spikerushes. In general, they are somewhat resistant to most herbicides and their control requires high rates of those chemicals used for submersed weeds. □

Acknowledgment

Partial support for studies on the spikerushes is being supplied by the U.S. Department of Agriculture, Agricultural Research Service (ARS) through their Cooperative Agreement No. 58-7B30-0-177.

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Male-flowering Hydrilla is Triploid in North Carolina

by

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¹Graham J. Davis

²George J. Pesacreta

Hydrylla (*Hydrilla verticillata*) growing in lakes in Wake County, North Carolina, was identified by William Haller in 1980 and had apparently been established in the area for several years. In September 1982 Dr. Thai K. Van identified staminate (male) flowers on plant material being maintained at Fort Lauderdale, Florida, which was originally obtained from Washington, D.C. (Vandiver et al. 1982). Following Van's identification of male flowers in Florida we established that male flowers were being produced in North Carolina at the same time.

Two different hydrilla genotypes have been found for the United States based on chromosome counts and isoenzyme studies (Verkleij et al. 1983). USA hydrilla II (2N=16) has been found in Washington, D.C., Maryland, and Delaware while USA hydrilla I (2N=24) has been found elsewhere (except for a tetraploid in Alabama). Formerly, male flowers were only considered to be associated with diploid plants (USA hy-

drilla II); however, chromosome counts on North Carolina male-flowering populations thus far indicate that they are triploid.

Hydrilla in North Carolina (2N=24) and USA hydrilla I in Florida (2N=24) evidently have different phenologies. Tuber production in North Carolina begins in late June and continues to early November whereas in Florida (USA hydrilla I) this occurs from October to May (Haller 1978). Although floral initiation appears to coincide with tuber production in both North Carolina and Florida, male flowers have not been observed on Florida plants. Hydrilla in North Carolina (2N=24) and USA hydrilla II (2N=16) are similar in that both produce male flowers and tuber production in USA hydrilla II begins by August in Delaware (Joe Joyce, personal communication). Until chromosome counts were made, we assumed that North Carolina hydrilla would be the "northern" variant (USA hydrilla II). Apparently this is not the case.

During the summer of 1983 male flowers were found in all four lakes studied in North Carolina (Lakes Anne, Wheeler, Crabtree, and Big Lake). Plants collected from all study lakes appeared to be monoecious (male and female flowers on the same plant). Female flower production began in early to mid-July and continued to late October. Male flower production was evident by mid-August and also continued to late October. Flower density was 140-165 per m² for female flowers and 70-130 per m² for male flowers. Neither fruits nor seedlings have been found.

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Waterhyacinth Control In California

by Larry Thomas
Co-Author Dr. Lars Anderson

Sacramento-San Joaquin Delta

The Sacramento-San Joaquin Delta, originally a tidal marsh formed in an overflow area of the Sacramento and San Joaquin Rivers, is generally considered to be the area bounded by the City of Sacramento on the north, the City of Stockton on the east, the City of Tracy on the south, and the Suisun Bay on the west. Prior to 1910, the Delta area was utilized primarily for livestock grazing; however, by 1924 after more permanent levees were constructed, the Delta became one of the major cropland areas of California, producing agricultural commodities worth in excess of \$400 million in 1981. The Delta includes approximately 270,000 acres of farmland considered to be one of the most fertile agricultural areas in the United States, containing 100 tracts and islands with the land surface ranging from 20 feet above sea level to 25 feet below sea level. The area is unique in that it is both a prime agricultural and recreational area as well as an invaluable fresh water resource and an important producing area of high quality natural gas.

The Delta, with approximately 150 marina facilities, provides a

unique recreational opportunity for the entire State of California accounting for about 80 million dollars of recreational expenditures annually while providing 12 million recreational days for the public.

The Delta has approximately 700 miles of channels and sloughs which are utilized very heavily for navigation and irrigation. The Sacramento and San Joaquin River channels within the Delta are maintained for deep draft navigation to the cities of Sacramento and Stockton respectively. The remaining waterways of the Delta have water depths ranging from 5 to 10 feet at low water and are heavily used by both the boating public and the general public.

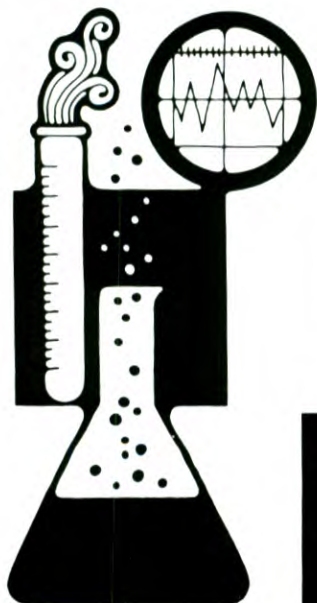
The Delta also plays a major role in the State of California's water transport system. Water storage in the foothill and mountain areas of northern California is released through the Delta during low flow periods. One-third of California (64,600 square miles) drains through the Delta area with outflow varying from 10 to 46 million acre feet annually with an annual average of 20 million acre feet. The major north to south water export point is on Old River

near the City of Tracy where both the State of California and the Federal Bureau of Reclamation pump water from the Delta for export to the south. During periods of low flow in the Delta, this water exportation from the southern part of the Delta actually creates a reversal of flow in Old River downstream from the pumping plants as well as in other waterways of the Delta.

Additionally, Delta waters also support a large population of resident fish and anadromous fish ascending and descending the Sacramento, Mokelumne, Stanislaus, Calaveras, and San Joaquin River systems. The California Department of Fish and Game estimates that 25 percent of the State's warm water and anadromous sportfishing and 80 percent of the commercial salmon catch is dependent upon the Delta.

Background and History of Waterhyacinth Introduction

Waterhyacinth plants have been known to exist in California as early as 1904 when their presence was discovered in Yolo County in a slough near the City of Clarksburg. By 1947, waterhyacinths had become a problem in some areas of the Sacramento-San Joaquin Delta. The Bureau of Reclamation experimented with methods of chemical control and actually made some chemical applications in Rock Slough west of Delta Road. In 1972, the Army Corps of Engineers was asked to investigate, as a possible flood hazard, the blockage of the Merced River by waterhya-



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cinths. The Corps indicated their subsequent investigation did not reveal a flood hazard. The problem occurred again in 1973; however, the Corps did not feel they could economically justify implementation of a long-term control program utilizing the herbicide 2,4-D but did recommend and offer to participate in an annual investigation of the river.

From 1973 until the drought years of 1976-77, there are very few recorded problems with waterhyacinths in the Sacramento-San Joaquin Delta or the San Joaquin River drainage basin.

Following and possibly because of the drought years with their resultant reduced flows through the drainage areas upstream of the Delta, the annual flushing of hyacinth plants through the system did not occur. The resultant increase in over-wintering plant material allowed sudden and severe summer growth which became an immediate and publicly apparent problem to the varied users of the Sacramento-San Joaquin Delta region.

The outcry of those impacted by

the waterhyacinth population brought about the introduction of Senate Bill 1344 on January 13, 1982, authored by Senator Garamendi and co-authored by Assemblyman Patrick Johnston.¹ SB 1344, which became effective immediately upon signature by the Governor on June 14, 1982, appropriated \$125,000 from the Harbors and Watercraft Revolving Fund to the Department of Boating and Waterways as the designated lead agency to implement a short-term program for waterhyacinth control and develop a long-range control program for the Sacramento-San Joaquin Delta and the Suisun Marsh.

In July, 1982, the Department formed a Waterhyacinth Task Force comprised of representatives of those agencies either most directly affected by the waterhyacinth problem or those having expertise in the area. Listed below are the agencies and their respective representatives.

State Agencies

Department of Boating & Waterways: Bill S. Satow/Larry J. Thomas

State Water Resources Control Board: Doug Albin/John Cornacchia
Central Valley Regional Water Quality Control Board: Wilton Fryer/Rudy Schnagl
Department of Food & Agriculture: James Wells
Department of Fish & Game: Brian Finlayson
Department of Health Services: Richard McMillan/Robert Hultquist

Federal Agencies

U.S. Department of Agriculture, Agricultural Research Service Aquatic Research Laboratory at U.C. Davis:
Dr. Lars Anderson
U.S. Bureau of Reclamation: Carl Tennis

Local Agencies

San Joaquin County Agricultural Commissioner: Erwin Eby
Contra Costa County Agricultural Commissioner: John H. deFremery

The purpose of the task force was to develop the conditions under which herbicides could be applied and the protocol for water quality monitoring to ensure that an economical and environmentally safe program was undertaken.

Control Plan

Long before the legislation was signed by the Governor, a series of meetings was held with State, Federal and local governmental agencies, private citizens groups, and the general public to determine the extent of the problems and to gather information relative to possible control measures. During this problem assessment period, a considerable amount of time was expended by the Department evaluating various control methods. The Department asked the Corps of Engineers' Waterways Experiment Station (WES) to develop both a short and long term control plan. A draft of this plan was available in April 1982 and was then presented to the appropriate Federal and State agencies for review and comment. Very little revision was necessary, and the final plan was submitted to the Department on May 3, 1982.

The plan developed by WES recommended an integrated program utilizing chemical, mechanical and

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¹Assembly Joint Resolution No. 64, authored by Assemblyman Patrick Johnston and filed with the Secretary of State on June 11, 1982, requested the U.S. Army Corps of Engineers to cooperate with the State in undertaking an aggressive program for waterhyacinth control.

biological control measures (a detailed biological control plan was submitted later with specific sites identified for release and monitoring of biological agents).

The recommended short-term measures were to utilize mechanical and chemical means with the introduction of biological agents to provide the long-term control. Theoretically, as the biological agents become established, the need for chemical and mechanical controls can be reduced with a resultant decrease in the cost of the program.

Mechanical Methods

The WES plan identified several possible mechanical control measures, such as in situ chopping of the plants and/or mechanized removal as well as the use of barriers to retain or to redirect the movement of the plants. The Department staff met with numerous people to review the various mechanical means that might be possible for physically removing hyacinths from the Delta. However, it became apparent after investigating the mechanical removal

methods and the costs associated with this type of control that the Department did not have the funding capability to carry out a sufficiently large removal program. The use of barriers, on the other hand, did appear to be a low cost mechanical measure that could have a significant benefit.

A test barrier was installed in Fourteen Mile Slough in the fall of 1982 to evaluate the feasibility of this method. This test indicated that barriers could, in fact, be successfully utilized to retain material in the nursery areas and prevent large masses of floating plants from blocking the navigable channels until the winter high flow period in the Delta. This concept is also being used to retain hyacinths in selected areas to provide habitat for the biological agents.

Chemical

The use of herbicides was identified in the plan as the major part of the short-term control program. The herbicides registered for use in California for this purpose in the summer of

1982 were Weedar 64® (2,4-D) and Diquat®. In the summer of 1983, Rodeo® (a formulation of glyphosate) was also registered. The chemical control program was to use 2,4-D wherever possible and to use Diquat® in those areas where 2,4-D could not be used.

Because the waterhyacinth control program was an entirely new program for the State of California and because of the multiple use of the Delta waters, it was necessary to develop a sophisticated water monitoring program for each herbicide application to be absolutely certain the label requirements were met and to build public confidence that herbicides could be used to control the hyacinth infestation without any degradation of the existing water quality. Therefore, in the summer of 1982 under the direction of Dr. Lars Anderson of the USDA/ARS Aquatic Weed Control Research Laboratory, two types of tests were conducted to determine the amount of 2,4-D or Diquat® that would enter the water following application of these herbicides for control of waterhyacinth. In one type of test, the actual amount of herbicide that reached the water surface after passing between waterhyacinth plants (or in some other way penetrating between foliage) was determined by using "floating" bottle samplers that were placed beneath the waterhyacinth canopy at the water surface. These float samplers contained known amounts of either distilled water or Delta water and were retrieved after application of 2,4-D or Diquat® in a test area. The amount of 2,4-D or Diquat® was then determined by standard analytical methods.

In the second type of testing, water samples were taken before and at various times after application of the herbicides to waterhyacinth mats. The locations of these water samplings were made so that the amount of herbicide entering the water immediately adjacent to the mats and at various distances downstream could be determined. The results from the first type of testing indicated that from 8 to 12 percent of the amount of herbicide applied to the plants was able to reach the water surface. These tests also



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indicated that, in the case of Diquat®, very little residue was detectable in the float samplers containing Delta water. This is primarily due to the rapid adsorption of Diquat® to dissolve and particulate organic materials in the Delta water. The results of the second type of testing showed that occasionally 2,4-D residues of 5 to 15 or 20 ppb were found immediately adjacent to the sprayed waterhyacinths, and that downstream, even less than one-fourth of a mile, levels were generally non-detectable or below 10 ppbw.

The information gained by these tests during 1982 was used to develop the monitoring and water sampling protocol for the operational program in 1983. Through the cooperative agreement between WES and the Department, in the fall of 1982, WES staff persons implemented larger scale field tests using both 2,4-D and Diquat® to determine the efficacy of the herbicide program developed by the task force and what residues could be anticipated. During this test period, a series of 1, 2 and 5 acre test plots were treated with 2,4-D using approximately 4 pounds per acre. Again, water sampling and analysis conducted by the USDA/ARS Aquatic Weed Laboratory indicated that the maximum level of residue found during this test was 13 ppb. Larger test areas were treated with Diquat®; however, these tests were primarily to determine the effect on late summer growth because the earlier tests by Dr. Anderson indicated that Diquat® residue is tied up so quickly due to the clay particles and organic material in the water that residue a few yards from the application site was non-detectable. The results of these tests and the water data gathered from them were used as the major data source in establishing the 1983 control program.

Biological Agents

Meetings were held with biological control specialists from the U.S. Department of Agriculture, WES, and the California Department of Food and Agriculture to determine which biological agents were effective in waterhyacinth control. The decision was made to initially introduce *Neochetina bruchi*, a

small, host-specific weevil. Dr. Lloyd Andres, Research Entomologist with the USDA/ARS in Albany, California, had done experimental work with this weevil and was familiar with the necessary background data that must be available to the reviewing agencies before permission could be obtained to import a non-native biological control agent into California. Therefore, he agreed to make inquiries of the control agencies. After receiving the necessary clearances from the controlling agencies and importing sufficient numbers of weevils, a positive identification and checks for any possible diseases were made. The weevils were maintained on waterhyacinth at the ARS Aquatic Weed Laboratory for several weeks before the first releases of the waterhyacinth-eating weevil, *Neochetina bruchi*, were made in Old River on July 2, 1982, with a second release on July 15.

Following the initial releases of *Neochetina bruchi*, Dr. Andres also obtained permission to introduce *Neochetina eichhorniae* and *Sameodes albiguttalis*. The weevils, *Neochetina bruchi* and *Neochetina eichhorniae*, were all collected from the field by WES personnel and then imported by Dr. Andres where they were positively identified and checked for pathogens before they were released into the nursery areas of the Delta. The *Sameodes albiguttalis*, a moth species, is being raised in the laboratory of the State Department of Food and Agriculture by the Biological Control Unit personnel and is then released into the selected sites.

The *Neochetina bruchi* have over-wintered in California and are spreading from the initial release sites. The other biological agents have not been in the field long enough to determine if they will over-winter and reproduce; however, it is anticipated that they will.

The 1983 Program

In developing the 1983 program, because of the limited funding, it was apparent that the most economical control method would have to be employed if any degree of control could be expected and, further, this control would have to be directed only at known problem areas. After discussions with WES,

it was determined that a chemical control program would be the most cost efficient plus a limited amount of mechanical control. The mechanical means to be employed would be the mechanical barriers rather than mechanical removal of the plant material. Additionally, continued releases of the biological agents were scheduled for four sites, with a subsequent release the latter part of October 1983 in a fifth site.

The major area of waterhyacinth infestation in the Delta is that area bounded on the north by State Highway 12, on the south by Old River, on the east by Interstate 5, and on the west by the Sacramento River. This large area was divided into four approximately equal smaller areas for herbicide treatment. Each of the smaller areas was assigned a team to be responsible for that specific area.

In California, permits are required from the County Agricultural Commissioner before the restricted herbicide 2,4-D can be applied, and the permit must be "site" specific. Based on the amount of hyacinths that might be expected in any specific area and the water data gathered in the 1982 field tests done by Dr. Anderson and WES, the major infestation area was divided into 2 to 3 mile "sites." Prior to any chemical applications being made, an overall county permit was obtained from each Agricultural Commissioner; and, before field operations began in any site, a Notice of Intent was filed for each site at least 24 hours prior to application of herbicide. Although the process may appear to have been rather cumbersome, in actuality it went very smoothly and did not delay the program.

During the field operations, a control team could treat a maximum of five acres per "site" and then had to bypass an adjacent site before beginning treatment again. The rationale for this limitation was based on the water data obtained from the 1982 field work done by Dr. Anderson and WES as a means to insure a wide safety margin. The Task Force felt confident that the water residue would be minimal if a maximum of five acres per site were treated.

During the chemical control effort, Dr. Anderson's staff, under the field direction of Robert Pine (ARS) took samples of the water before and immediately after each herbicide application and per-

EXAMPLE
Summary of 2,4-D Residues in Sacramento Delta

Date	Location	Site	Time	2,4-D (ppb)	
6/1/83	Paradise Harbor	Pre	0900	1A	0.1
				1A	0.2
				1B	0
		Post	0957	2A	0.4
				2B	0.2
				2C	0
			1159	3A	1.5
				3A	0.9
				3B	0.3
				3B	0.1
				3C	0.4
				3C	0.7
		Pre	1330	1A II	0
				1B II	0
		Post	1408	2A II	0
				2B II	0
				2C II	0
		Post	1510	3A II	0
				3B II	0
				3C II	0.8
					0.7

formed the water analysis for 2,4-D. Throughout the chemical control effort, the water analysis detected only minimal (if any) residue that was well below Federal tolerances of 100 ppbw. An example is shown in the following table.

The County Agricultural Commissioner's staff provided field data regarding the specific location of any sensitive agricultural crops. Because of their input into the waterhyacinth control program, there was no reported damage to any agricultural commodity in any county.

Environmental Concerns

When the use of herbicides was proposed as the major short term control method, the Contra Costa Water District became concerned because the water district extracts water from Old River at Rock Slough and transports the water across the Delta to the East Bay for use as a domestic water supply to several cities. Throughout the discussion of the use of herbicides to control waterhyacinth in the Delta, the representatives of this district had expressed their concerns relative to the use of 2,4-D in the Delta and in particular any-

where close to Rock Slough. The California Department of Health Services wrote a letter to the Contra Costa Water District which indicated that they felt 2,4-D could be used safely and that their opinion was based on water analyses from earlier test plots as well as their experience in working with 2,4-D. The Health Department stated that they felt the residue would be minimal or non-detectable. In addition, the water treatment facilities use activated charcoal in treating the water for domestic consumption which will remove any 2,4-D from the water. However, the district still expressed concern so an agreement was reached whereby no spraying would occur in Rock Slough or in Old River one mile above or below the intersection of Rock Slough and Old River or in Werner Dredger Cut north of the railroad track at Orwood Resort.

Throughout the 1983 program, beginning in the late spring, there were a number of environmental concerns raised by some State legislators, local political leaders, the Contra Costa Water District and a few private citizens in Contra Costa County. Those few private citizens petitioned the Superior

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Court in Contra Costa County and were successful in obtaining a Temporary Restraining Order on May 11, 1983, against the use of 2,4-D in that county. Shortly thereafter, the Department, through the State Attorney General's Office, notified the Superior Court Judge of its intent to utilize the herbicides Diquat® and Rodeo® in an attempt to alleviate some of the infestation. The private citizens again petitioned the Judge to prevent the use of these herbicides as well; however, on July 29, the Judge refused to extend the restraining order to Diquat® and Rodeo®. The Department then began immediate applications of Diquat® in Contra Costa County.

Results of the 1983 Control Program

The control program in San Joaquin County has been very successful this year and, as a result and in direct contrast to last year at this time, the waterways of San Joaquin County are clear of hyacinths. Marina operators, farmers, and recreationists are all very pleased with the results of the waterhyacinth control program. In Contra Costa County, however, due to the court order against the use of 2,4-D, the waterhyacinth

problem became quite severe by the fall of 1983. This infestation coupled with the tidal currents and the predominately westerly winds moved the hyacinth mats into previously cleared areas in San Joaquin County. The Department is monitoring the situation very closely and has retreated some of the reinfested areas of San Joaquin County.

The Control Program for the Future

The 1984 control program has not, at this time, been finalized and will depend to some extent upon the outcome of the trial in Contra Costa County. Additionally, there is a strong possibility that a significant reinfestation from the upstream area of the San Joaquin River may occur next year. If this does occur, it will mandate another all-out effort early in the spring to reduce the total biomass as early as possible. Probably the same basic control plan will be used, utilizing 2,4-D as the preferred herbicide, barriers to trap or divert the hyacinth mats, and additional biological agents.

It is anticipated that certainly by the end of 1985 (barring an unfavorable decision from the Superior Court in Contra Costa County) there will be a significant

reduction in the waterhyacinth population resulting in a corresponding reduction in herbicide applications. By that time also, the colonies of biological agents should be established to the point that their impact on the hyacinth population should become apparent.

Total eradication of the waterhyacinth in the Sacramento-San Joaquin Delta will probably not occur. We are confident, however, that the control measures developed by the staff of WES and the Waterhyacinth Task Force will be very effective in attaining as near total eradication as possible while protecting the environment of the Sacramento-San Joaquin Delta, human health, and wildlife habitat. □

Acknowledgments

The number of individuals involved in the Waterhyacinth Control Program is too extensive to list. However, the cooperative spirit and assistance from all the public agencies and individuals from the marina and agricultural communities involved with the program was outstanding. It was this cooperative spirit and assistance that made the program successful.

Common Reed

Phragmites australis (Cav.) Trin. ex Steudel

Ted R. Batterson¹ and David W. Hall²

The large grass, *Phragmites australis* (Cav.) Trin. ex Steud., is both a boon and a bane to man. It has been said that it is the most widely distributed flowering plant in the world being found throughout the United States, South America, Europe, Asia, Africa, and Australia. It extends throughout Eurasia to a latitude of 70 degrees north and into the south temperate zone. It is most abundant in temperate regions, especially in the Old World, but it is also prevalent in sub-tropical areas. It is native to North America and in the United States extends from the Canadian border to the southern portion of Florida. In many areas that it occurs it is considered a weed and is listed in one book as one of the world's worst. However, in some areas, this abundant growth has been put to good use for both man and wildlife.

There has been some confusion over the taxonomy of this plant. The proper name is *Phragmites australis* (Cav.) Trin. ex Steudel which has and sometimes still is referred to as *Phragmites communis* Trin. Here in America this plant is called the Common Reed. The species name "australis" is Latin meaning southern, referring to the warmer regions in which it was first identified. It usually grows near water and often the rhizomes permit massive continuous overgrowths which can restrict water flow. The genus name "Phragmites" is derived from the Greek word "phragma" for fence or partition, referring to the zonation of growth along water.

The Common Reed is a tall (2-5 meters) perennial grass that has an extensive rhizome system. Many times stolons are present also. The stems are leafy from the base to the seedhead and when older are

cane-like and quite smooth. The leaves are composed of a sheath, ligule, and blade (Figure 1). The sheath is the lower part of the leaf which surrounds the stem and is always open on one side. The blade is the long, broad, flat portion at the upper end of the sheath. At the junction of the sheath and the blade on the stem is the ligule. The ligule is composed of a membrane which can be up to 0.4 mm long with a fringe of hairs up to 0.5 mm long. The flat leaf blades can be as wide as 2.8 cm and 63 cm long with a few hairs just above the ligule at the base of the blade. The dense seedhead is 27 to 70 cm long and is composed of many small spikelets. Each spikelet is from 9 to 16 cm long and is composed of a cluster of 2-4 flowers. The individual flowers are from 10 to 13 mm long. The minute stalks for each flower are hairy but the flowers themselves are not and have a smooth appearance. Mature plants of *Phragmites* are easily

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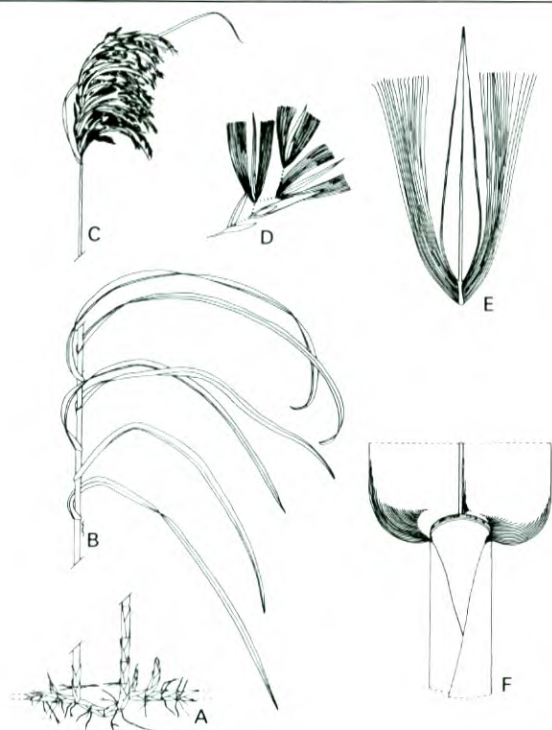


Figure 1.
Common Reed [*Phragmites australis* (Cav.) Trin. ex Steudel]: A. rhizome; B. leaves; C. seedhead; D. several flowers; E. single flower; and F. ligule.
Drawing by Wendy Mahon-Hils, Botanical Illustrator.

separated from two similar weedy grasses, Giant Reed (*Arundo donax* L.) and Burma Reed (*Neyraudia reynaudiana* (Kunth) King & Hitch.), by the silky beard at the base of the seedhead. This beard is not present on Giant Reed or Burma Reed.

Common Reed is classified as a semi-aquatic plant that grows in a variety of habitats. It is tolerant of saline conditions, as indicated by its occurrence in salt marshes, but its performance decreases with increasing salinity. Studies have shown that 15-20 parts per thousand is the upper limit of salinity (approximately 50% of seawater). It is quite remarkable for its strong, tall aerial stems which are similar in form and anatomy to terrestrial grasses of drier sites. However, the basal parts are surrounded by much the same environment as a totally submersed plant and in turn have similar morphological characteristics to them. Because its roots are always in water or saturated soil and its stems high in the air, the plant has developed air passages to supply the roots and other submersed parts with oxygen.

The extensive, deeply penetrating perennial rhizome system of a reed stand can constitute up to 75% of the total biomass. The rhizomes are hollow and up to several centimeters thick. They serve as a storage area for nutrients and photosynthetic products, facilitating rapid regrowth independent of photosynthesis. They can also serve as source for spreading the plant within a community, growing at a rate of up to 2 m per year. Individual rhizomes can be up to 20 m long. Plant parts, such as the rhizome, do not live much more than 3 to 8 years, but clones of the plant have been reported to be up to 1,000 years old. Studies conducted in Europe have shown that 30 year old stands have shown no decline in productivity. Even though the rhizome serves as the main source of reproduction, seed production is usually quite high; but where the reed is already well established, optimal conditions for germination are not easily met. The seed, unlike the mature plant, cannot tolerate more than a few millimeters of water for successful germination. The growth is initially very slow, since the seedling is very sensitive to competition for light and nutrients.

The plant grows on a wide
continued on page 20

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variety of substrates, from coarse gravel to fine organic soils. High yields result more from climate and nutrient availability than from the type of substrate in which they are growing. It is thought that most of the nutrients are derived from the soil, but when the stems are subjected to nutrient-enriched water, finely branched roots form on the lower portions and uptake from these structures probably is quite significant. Reed stands are often monospecific and the shading from the canopy is substantial, effectively reducing competition from other plants. The plant has a high leaf area index which allows for an efficient utilization of incoming radiation.

The Common Reed displays a great amount of morphological variability which is due to the plant's genetic diversity. Chromosome numbers vary greatly, from $2n=24$ to $2n=96$; the most common number is $2n=48$. Even between adjacent clones there can be marked physical differences in appearance of the plants.

The plant has had a long history of use by man. Ancient Egyptians used the stems as building material for houses and rafts. In England and other European countries it has been used for many years as thatching (Figure 2). The Romanians have used the plant extensively, establishing large areas that have been under cultivation in the delta area of the Danube River since 1956. Most of the reeds are turned into pulp for the production of printing paper. Other products are cemented reed blocks, synthetic fibers, alcohol, fuel, cardboard, cellophane, insulation materials, and fertilizer. The annual harvests are very substantial and have become an important part of the Romanian economy. Scientists from Germany found the plant to



Figure 2.
A building in Europe thatched with Common Reed (Photograph courtesy of David L. Sutton).

be an effective biological filter for waste water renovation as have scientists from Australia. The Swedes have found the plant to be a viable alternative energy source. They compress the harvested aerial stems into bales, pellets, or bricks which are then burnt in modified furnaces.

High yields of this plant are dependent upon an array of environmental factors, two very important ones being nutrients and water. To exploit that fact, we initiated studies in south Florida for determining what sort of biomass yields we could obtain by growing the plants in high nutrient concentrations with unlimited water. This was accomplished by using composted sewage sludge as the growth medium and constantly irrigating the plants with secondarily-treated sewage effluent. Both of these are waste products which are enriched with nutrients. By the second year of growth, the plants were almost 5 m tall (see Figure 3) and harvests of the aerial stalks yielded an average of 95 metric tonnes dry weight per hectare per year. This approaches the reported values for waterhyacinth which is claimed to be the highest yielding



Figure 3.
Common Reed grown in composted sewage sludge and irrigated with secondarily-treated effluent in south Florida.

plant in the world. What is interesting about our results is that they are only for the above-ground portions of the plant which probably only constitute 25% of the total plant biomass. The remaining 75% is below-ground, giving rise to the next year's growth.

These preliminary results and knowledge of the reeds biology would indicate that this plant should have tremendous potential as an energy crop, an alternative to our dependency on fossil fuels. In addition, its wide dispersal and genetic variability (which should be able to be manipulated through genetic engineering) should give the plant universal appeal. □

Herbicides and Hybrids

Dr. John A. Osborne¹

and

Ms. Janine L. Callahan²

INTRODUCTION

The hybrid grass carp, a cross between the male bighead carp, *Hypophthalmichthys nobilis* Rich. and the female grass carp, *Ctenopharyngodon idella* Val., has a

characteristic low feeding rate associated with slow growth; feeding rates (consumption expressed as a percent of body weight per day) for 1980 hybrid grass carp have been reported to vary between 24% (Callahan and

Osborne, 1983) and 35% (Hestand et al., 1983). Due to this low consumption rate, the hybrid grass carp, in most field trials in Florida, has been incapable of hydrilla control even when stocked at relatively high rates (118 fish metric ton⁻¹-fresh weight hydrilla) (Osborne, 1982). On the other hand, grass carp have been shown to eliminate

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hydrilla when stocked in spring at the rate of 20 1-year old fish metric ton⁻¹-fresh weight hydrilla. Since large grass carp (greater than 11 kg) have a feeding rate similar to the hybrid grass carp and much lower than 1-year old grass carp (Callahan and Osborne, 1983; Osborne and Sassic, 1979) and are known to control hydrilla when assisted with herbicide (Lake Jane, Orlando, Florida), it was thought that perhaps hybrid grass carp might be useful under similar circumstances, i.e. used as a bio-regrowth-control agent after vegetation reduction with herbicide. A herbicide-hybrid trial was undertaken in Blue Lake, Longwood, Florida to determine the feasibility of this approach.

Methods and Materials

Blue Lake, a 1.0 acre hydrilla infested pond, had been used as a test site for 1979 hybrid grass carp previous to this study (Osborne, 1982_a). Blue Lake was renovated with rotenone in August, 1979, to remove the wild fish before the 1979 hybrids were stocked. At the termination of the 1979 hybrid grass carp trial, Aquathol (150 lb/acre) was applied to the lake in

June, 1981. The 1981 hybrid grass carp, purchased from J. M. Malone and Son Enterprises, were stocked into Blue Lake to start the herbicide-hybrid trial at the rate of 750 fish acre⁻¹ (80 fish metric ton⁻¹-fresh weight hydrilla) in November, 1981. Blue Lake was again treated with herbicide (Aquathol, 100 lb/acre and Diquat, 2 gal/acre) in August and September, 1982 to reduce the hydrilla biomass in order to remove the hybrids. The hybrids were removed with 0.1 ppm rotenone in October, 1982 (after 325 days). These fish were housed in an experimental pond on the UCF campus until February, 1983, at which time they were returned to Blue Lake (224 fish). An additional 65, 1981 hybrid grass carp were stocked into Blue Lake making a total of 289 hybrids (667 fish metric ton⁻¹-fresh weight hydrilla). After 209 days and following an application of herbicide (Aquathol K, 5 gal/acre) to reduce the vegetation biomass, the hybrid grass carp were removed in September, 1983 using 0.1 ppm rotenone.

The effect of the herbicides and hybrids on the hydrilla in Blue

Lake was determined by monitoring the vegetation biomass on a bimonthly schedule (October, 1981-October, 1983) using the Osborne submersed aquatic plant sampler (APHA, 1981).

Results

Of the initial number of hybrid grass carp stocked in Blue Lake in November, 1981, only 41.1% remained by October, 1982; this accounted for an average loss of 42 fish month⁻¹. A total of 308 fish were removed from the lake. Since Blue Lake did not contain a wild fish population, the high mortality of the hybrid grass carp was probably due to genetic deficiencies caused by hybridization. The 1981 hybrids had a mean growth rate of 1.3 gm fish⁻¹ day⁻¹ and a mean weight of 504.8 gm fish⁻¹; the growth rate of these fish was 28.2% faster than for the 1979 hybrid grass carp that had been previously stocked into Blue Lake (Osborne, 1982_a). For comparison, grass carp stocked into Florida hydrilla infested lakes generally have a growth rate approaching 15 gm fish⁻¹ day⁻¹. The mean total length of the 1981 hybrid grass carp increased from 18.3 cm to 34.7 cm within the 325 day trial. There was little variation between the size of individual fish. The hydrilla biomass in Blue Lake at the time of the initial stocking of the 1981 hybrids was 1.88 kg m⁻²-fresh weight (December, 1981). At this time, the hydrilla biomass began an immediate increase which continued throughout the 1982 growing season. By August, 1982 the hydrilla biomass had reached 3.99 kg m⁻²-fresh weight, Figure 1. The percent frequency of occurrence (coverage) over the sampling period (December, 1981-August, 1982) was 100%. There was no indication of feeding by the 1981 hybrid grass carp on the hydrilla. It is suspected that the hybrid grass carp, being principally a leaf feeder (Osborne, 1982_a), probably stimulated the high rate of plant production in Blue Lake by causing the hydrilla to branch.

After herbicide was applied in September, 1982 the hydrilla biomass declined rapidly, Figure 1. It had decreased to 1.42 kg m⁻²-fresh weight by October, 1982 at which time the 1981 hybrid grass carp were removed. The biomass continued to decline throughout the winter and was only 0.08 kg m⁻²-fresh weight in February, 1983 when the 1981 hybrid grass carp

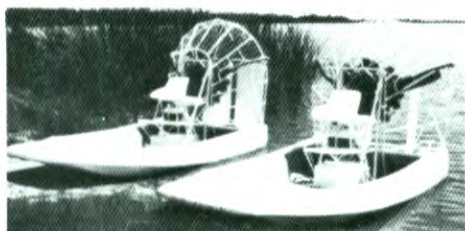
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