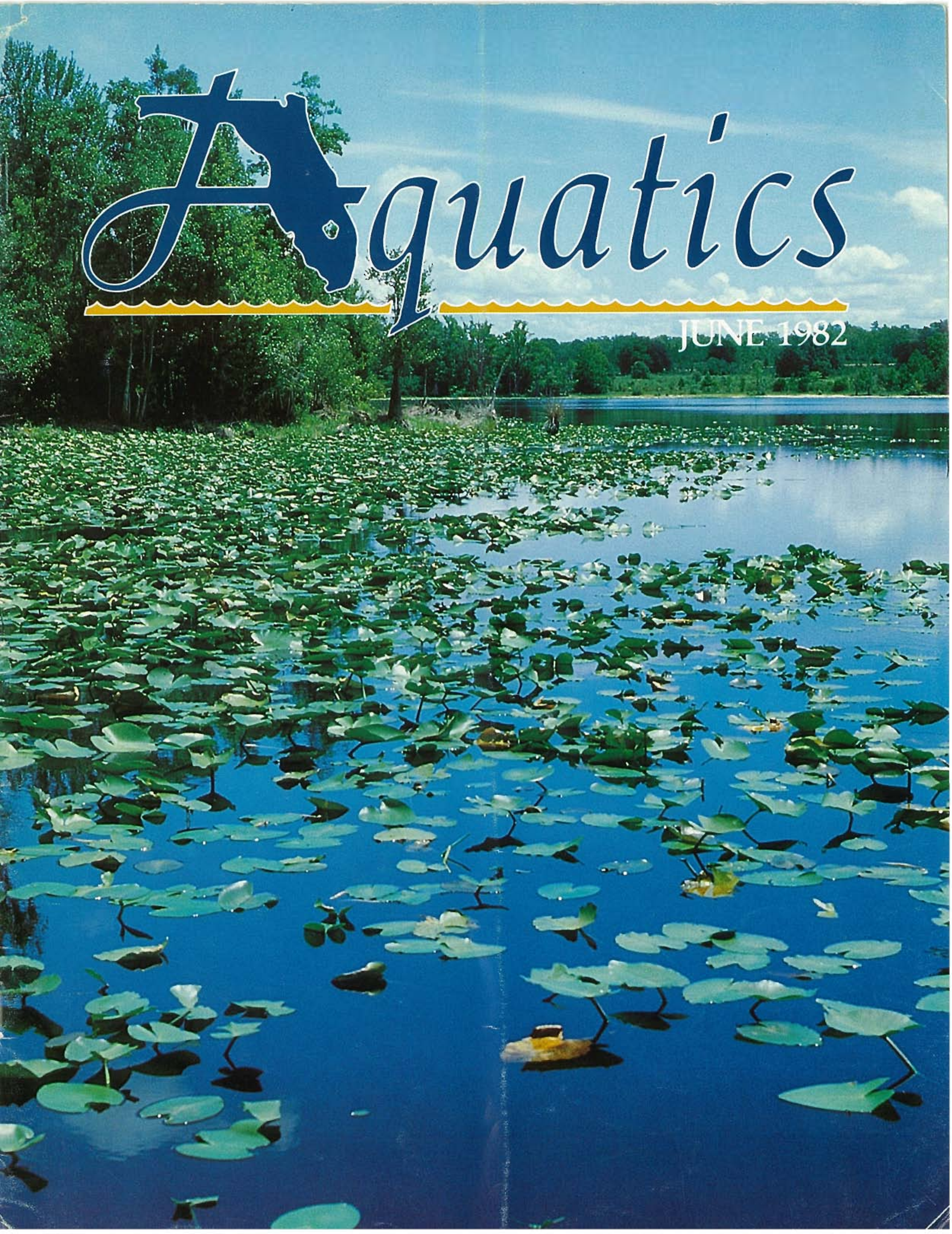
Aquatics

JUNE 1982



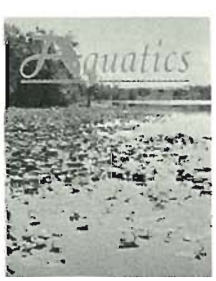
EDITORIAL

Florida has an aquatic weed problem equal to any in the world which has necessitated many aquatic weed control programs within the state. The Florida Department of Natural Resources, Bureau of Aquatic Plant Research and Control has long been the lead agency in aquatic plant control in Florida. During its early years the Bureau's primary thrust was an extension-education-regulatory approach that generally resulted in a feeling of mutual trust between the aquatic plant management industry and the Bureau. This approach also gave the Bureau a position of strong leadership within the field. During the past two years, the Bureau has been undergoing an apparent philosophic change to a legalistic-regulatory outlook, which has resulted in general mistrust.

After working for nearly two years on 16C-20, after several public workshops, after considerable input from FAPMS members, it looked like 16C-20 as approved in December by the Governor and Cabinet would be a workable document. Rule 16C-20 became effective April 9, 1982 but not without clouds. DNR has further advised that it will move to further revise 16C-20 since it is under scrutiny by the Joint Administrative Procedures Committee.

Florida is looked to internationally to provide information and lead operational and research efforts toward safe biological, chemical and mechanical weed control. We have done such a good job that the vast majority of the people in Florida are unaware of how serious a problem aquatic weeds can become. Aquatic plant management, the aquatic plant management industry and the Bureau cannot effectively move forward in the present mood. Let us hope that the leadership role in aquatic plant management is not lost totally as the Bureau intensifies its regulatory responsibilities. Let us strive for a new sense of trust, understanding and cooperation.

PAUL C. MYERS



THE COVER
Ross Lake, Katherine Ordway Preserve, Putnam County

Photo By Anita Tiller

Aquatics

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FAPMS ANNUAL MEETING / *October 27-29, Orlando*

The Aqua-Vine Section of "Aquatics" has been added to provide information on current events and recent publications from industry and government to increase the dissemination of aquatic plant control techniques and regulatory changes. Complete copies of reports mentioned in this section can be obtained on request to the respective authors or the Editor of "Aquatics."

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.

CORRESPONDENCE: Address all correspondence regarding editorial matter to Paul C. Myers, Editor, "AQUATICS" Magazine, 310 E. Thelma St., Lake Alfred, FL 33850.

The Watermilfoils of Florida

by
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The watermilfoils belong to the economically important, diverse genus *Myriophyllum,* and consist of approximately 50 aquatic, semiaquatic and terrestrial species with a cosmopolitan distribution. Both *M. aquaticum* (Parrot-feather) and *M. spicatum* (Eurasian Watermilfoil) are internationally noxious aquatic weeds, while at least 10 species are grown worldwide in aquariums and fishponds. Five species that occur in Florida have been sold as aquarium plants throughout the world. According to Aiken (1981), 13 species of *Myriophyllum* occur in North America and 10 of these species are native to this continent. Six species including *M. aquaticum, M. spicatum, M. verticillatum,* and *M. heterophyllum, M. laxum* and *M. pinnatum* occur in Florida. The watermilfoils are an excellent spawning media for fish, give shade and shelter for fry and provide a substrate for microfloral and microfaunal colonization. In addition these plants have a role in gas and nutrient cycling, water clarification and affect water circulation. These attributes are mainly due to the fact that watermilfoil leaves have the highest surface area to volume ratios of all aquatic macrophytes.

The exotic M. spicatum *(Eurasian Watermilfoil) crowding out native* M. heterophyllum *(Variable-Leaf Watermilfoil).*

Watermilfoils, as their generic name *Myriophyllum* implies, possess a "myriad of leaves" which are finely-dissected into filiform segments. The phyllotaxy within the genus is usually whorled, although several species exhibit alternate, opposite or a combination of these leaf arrangements. Watermilfoils are typically submersed plants,

Terrestrial form of M. aquaticum *(Parrot-feather) an exotic introduced from South America.*

although their inflorescences are emergent and possess the definitive taxonomic characteristics for the group. The uppermost portion of an inflorescence is staminate, the lowermost is pistillate and the middle portion is bisexual. All flowers are inconspicuous, have four sepals and are subtended by two bractlets and a bracteal leaf. Both staminate and bisexual flowers possess four deciduous petals, while the pistillate flowers lack petals. The staminate flowers possess four to eight stamens, and the pistillate flowers possess four plumose, recurved stigmas. The fruit is four-lobed and splits into four nutlets that are released into the water.

Many of the species in Florida are similar morphologically and exhibit phenotypic plasticity. This phenotypic plasticity is evident in *Myriophyllum's* morphological responses to current velocity, light, pH, salinity, substrate and temperature. In addition, several species form morphologically distinct terrestrial forms when stranded. Many of the taxonomic problems within the genus are due to this phenotypic plasticity.

The introduction of *Myriophyllum spicatum* (Eurasian Watermilfoil) to North America has augmented the taxonomic confusion within the genus. *M. spicatum* is morphologically similar to several watermilfoils in North America, and is difficult to distinguish from *M. verticillatum* in Florida. Although morphologically similar, *M. spicatum* is ecologically more aggressive than all other species in the genus. *M. spicatum* has become a serious weed throughout the world and adversely affects recreation, water supplies, transportation, flood control, mosquito control and fish and shellfish production. *M. spicatum* successfully outcompetes all other aquatic macrophytes in Florida's brackish-water habitats and is a problem in certain fresh-water habitats in the state. The weediness of this species is ascribed to its ability to tolerate a wide range of pH, to withstand varied nutrient and salinity conditions, and to survive depths of up to 17 meters. *M. spicatum* also forms terrestrial plants when stranded. *M. aquaticum* (Parrot-feather), which was the first exotic *Myriophyllum* to be introduced to Florida, also may be a problem in certain areas of the state. A native of South America, this amphibious *Myriophyllum* is, however, not as notorious as *M. spicatum. M. spicatum* was first reported in Florida in 1964 in the Crystal-Homosassa River Basin. In 1966 *M. spicatum* was reported in the Spring Creek arm of Lake Seminole and spread into Florida. Other areas of infestation in the state now include Deer Point Lake in Bay County, the Suwannee River, the St. Johns River, the Cassahowitzka River and recently Apalachiola Bay.

M. spicatum's rapid spread across Florida is attributed to its ability to produce new plants not only from the nutlets, but also from vegetative fragments and specialized deciduous axillary buds. The nutlets, which float temporarily after being released from the inflorescences, soon are dispersed by wind, water currents or waterfowl. Waterfowl also disseminate the slime-covered deciduous axillary buds which adhere to their feet. During autumn the inflorescences and vegetative branches undergo fragmentation and are carried along by

Continued on page 19

Submersed vegetative portion of M. spicatum.


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Hydrilla—Miracle or Migraine For Florida's Sportfish

by
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University of Florida
Gainesville, Florida 32601

The rapid spread of hydrilla through Florida's waters has caused many heated arguments among both sportfishermen and professionals on its actual influence on our fish populations. Opinions have ranged on hydrilla coverage from total elimination to little or no need for hydrilla control. The boater and water skier see only one solution, eradication. Many avid bass fishermen who have adapted their fishing styles to fishing dense vegetation feel hydrilla has been a definite bonus to our lakes. They are interested in only limited vegetation control confined to access points and boat trails. We have been documenting the effects of various levels of hydrilla coverage on Florida's sport fishes since 1974, and have been able to determine that it can cause serious detrimental changes in our fish populations (Table 1).

Lake Baldwin and Lake Wales

Our initial studies were conducted from 1974 to 1978 with the Florida Game and Fresh Water Fish Commission on Lakes Baldwin and Wales. Both study lakes had, at one point in time, dense stands of hydrilla; vegetation levels were fluctuated through the years by the use of grass carp and aquatic herbicides. Largemouth bass, bluegill and redear were collected seasonally with electrofishing gear, then individually weighed and measured allowing us to determine their coefficient of condition or condition factor. This is a relationship of weight to length reflecting the fish's relative plumpness and indirectly a measure of fish growth. Hydrilla coverage had to be in excess of 80% before bluegill or redear revealed reduced condition factors. Their diets of small insects and snails appears well suited to the presence of hydrilla.

Harvestable largemouth bass (>10 inches) had extremely low condition factors in both study lakes whenever hydrilla exceeded 30% coverage. Juvenile largemouth bass (<10 inches) did not reveal any reduction in growth until hydrilla covered 50% of the lakes. This difference in impact upon harvestable versus juvenile bass is directly related to dietary requirements for optimum growth. Bass <10 inches can efficiently utilize a diet of insects, shrimp and small fish while larger bass require a strict diet for optimum growth. Hydrilla infestation eliminates the gradient between open water and submersed vegetation that exists within most of our native aquatic plant communities. Florida largemouth bass need this open water-vegetation edge to feed on fish they require for good growth.

Lake Pearl

Lake Baldwin and Lake Wales showed reduced sportfish condition will be a direct result of hydrilla infestation, however, we did not determine actual growth rates of bass or their population structure. We have intensively monitored bass populations in Lake Pearl since 1979 by tagging all captured fish with individually numbered floy dart tags. This allows both population estimates and individual growth rates to be calculated when tagged fish are recaptured at a later date. Lake Pearl had hydrilla levels in excess of 80% coverage and 40% volume infestation during 1979, 1980 and 1981. Grass carp and herbicides have been utilized to reduce the hydrilla standing crop and by March 1981 percent cover is less than 50% and volume infestation is below 20%.

Table 1. Summary of impact of hydrilla on sportfish populations

Weed level	Fish species	Impact
>80%	Bluegill Redear Largemouth bass	stunted population for all species; skewed to large numbers of non-harvestable individuals characterized by little or no growth; extremely high survival of young of year fish due to lack of largemouth bass predation
50 to 80%	Bluegill Redear	No reduction in bluegill or redear growth; large populations of small sunfish present due to lack of bass predation
	Largemouth bass	same impact as 80%
20 to 50%	Bluegill Redear	no adverse impact
	Largemouth bass	good growth for bass <10 inches; however, large reduction in growth once fish reach 10 inches due to inability to effectively capture fish for food
<20%	Bluegill Redear Largemouth bass	no detrimental effect on any species; provides increase cover and therefore a potential for increase in standing crops of sportfish.

First year bass growth in Lake Pearl was less than 6.4 inches for the 1978, 1979 and 1980 year classes. First year growth should approach 8 inches in central Florida lakes, but in the presence of hydrilla it is reduced to 6 inches. Our tagging data indicates an even greater growth reduction occurs in subsequent years. Lake Pearl bass have taken three years of growth to attain minimal harvestable size (10 inches). Other studies have shown Florida largemouth bass should reach harvestable size by their second growth year. Bass growth in Lake Pearl after 10 inches is best described as near maintenance with tagged individuals not attaining lengths in excess of 14 inches. Although the total standing crop of harvestable bass is theoretically large (37 fish per acre), the population is skewed almost entirely (86%) to fish 10 to 14 inches which are not growing and exhibit all characteristics of a stunted population. The larger bass are growing at a higher rate than the intermediate fish, however; their populations can be characterized as static with little or no recruitment occurring. The problem of slow growth for intermediate bass is further compounded by annual recruitment of younger fish resulting in a population with annual immigration with very little subsequent emigration through growth. A tremendous forage base of small fish is present within the hydrilla, however; the intermediate size bass can not efficiently utilize the forage due to the physical barrier caused by the plants occupying the entire water column. Unlike the smaller fish, they can not maintain adequate growth rates utilizing a diet of aquatic insects and vegetation-dwelling fishes.

Summary

Our studies have revealed hydrilla coverage of 50% and a volume infestation greater than 20% will cause dramatic reductions in sportfish growth resulting in populations skewed to high standing groups of sub-harvestable individuals that are not capable of increased growth until hydrilla levels are reduced (Table 1). The population of larger harvestable bass (>14 inches) will become extremely reduced due to little or no recruitment from the stunted stock of 10 to 14 inch intermediate sized bass. If a viable population of harvestable sportfish is a management goal in a hydrilla infested water body, some form of aquatic vegetation control will be mandatory to prevent hydrilla coverage and volume levels from exceeding 50% and 20% respectively. When resources are available, target control levels should be maintained at no more than 30% coverage and 10% volume infestation for maximal fish growth and, in turn, high standing crops of harvestable sportfish.

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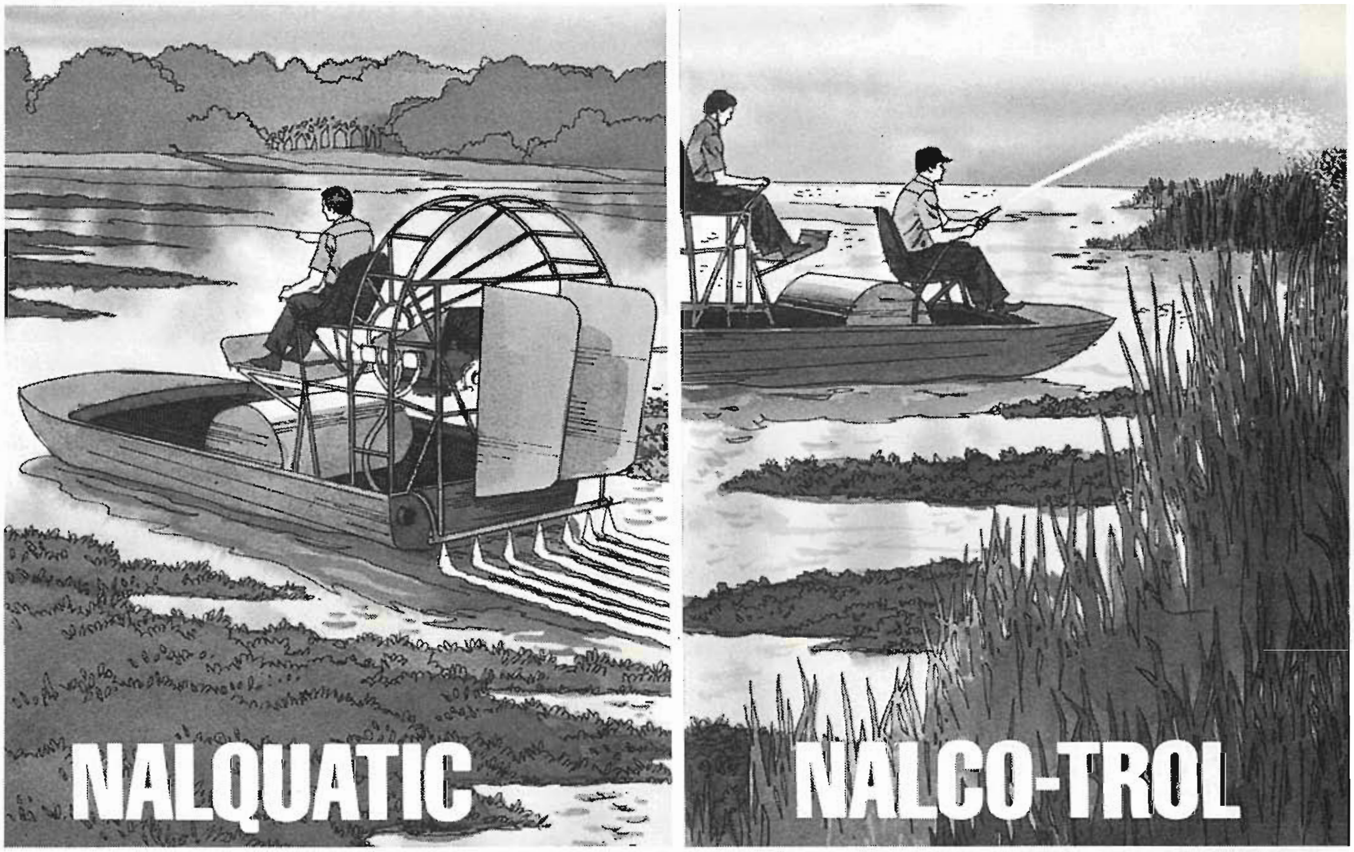

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The Waterhyacinth Weevils

NEOCHETINA EICHHORNIAE AND N. BRUCHI

by
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Research Entomologist
Aquatic Plant Management Laboratory
USDA, ARS, SR
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Waterhyacinth is a serious problem throughout the tropical areas of the world, although this was not the case a mere 100 years ago. It was virtually unknown outside of the Neotropics until the 1880's but, for reasons that can only be speculated upon, almost simultaneous introductions of waterhyacinth occurred throughout the world in the half-century between 1880 and 1930. By the end of this period it was established in such diverse regions as Australia, India, Southeast Asia, Indonesia, Egypt, South Africa and the United States. In fact, it had become adventive in India, Java, Australia and the U.S. between 1884 and 1896.

Although waterhyacinth was originally imported as an ornamental, it soon escaped to lakes, rivers, ponds, and canals and became a serious problem. This was especially true in underdeveloped countries where people's livelihood depended upon access to fishing grounds. The consequences of waterhyacinth infestation became painfully obvious and nearly every conceivable use of water resources was impaired where infestations became severe.

Over the past century almost every means of control imaginable has been attempted including everything from kerosene burners to laser beams. One of the first chemicals used was sodium arsenite, which proved toxic to a wide variety of organisms other than waterhyacinth. The development of 2,4-D in the 1940's finally provided a safe and effective means of control. Unfortunately, chemicals are of little use to the native peoples in countries where the most serious problems exist. Also, within the past decade, these chemicals have become so expensive that price has begun to restrict their use.

Biological control of waterhyacinth was first given serious attention in the 1960's. At that time a snail (*Marisa* sp.) and the West Indian Manatee (*Trichechus manatus*) were even considered as possible biological control agents. In 1968, Dr. B.D. Perkins was assigned the task of determining if there were any insects on waterhyacinth in its native range that might be useful as biological control agents.

The decision to begin research on the biological control of waterhyacinth necessitated a determination of where to search for natural enemies. In selecting a search area, several criteria were considered. First, the area of origin of the weed species was determined. The area in which the plant species has existed for millennia is where it is most likely that herbivores have had sufficient time to evolve specific relationships. It is the area where one would expect herbivores to have adapted to feed exclusively on the plant. A second consideration was the climate of the area where the biological control agents were to be used. Ideally, herbivores are selected from regions which are climatically similar to the areas where they are to be introduced. Other practical considerations include such things as political stability and the availability of goods and services in countries where the research is to be conducted. Because waterhyacinth is native to South America and because the Buenos Aires region is climatically similar to the area of distribution of waterhyacinth in North America, Argentina was chosen as the site to begin studies.

Over the course of several years many potentially useful insect species were found in South America. Through a process of elimination, the field of candidates was narrowed to a few species which seemed to feed exclusively upon waterhyacinth. One of the most promising was a small sub-aquatic weevil thought to be *Neochetina bruchi*. Subsequent taxonomic investigation revealed that these weevils actually represented two species, *N. bruchi* and the previously undescribed *N. eichhorniae*. Research on the biology and host specificity of these two species was begun in the late 1960's. Several years of research were required to insure that these insects would not damage economically important crops or beneficial plants if they were released in the United States. The scientists responsible for this research were Dr. B. D. Perkins and Dr. C. J. DeLoach of the U.S. Department of Agriculture, Agriculture Research Service (USDA, ARS). The project was funded by the U.S. Army Corps of Engineers, Aquatic Plant Control Research Program and the Florida Department of Natural Resources. The culmination of this project was the release of *N. eichhorniae* and *N. bruchi* in 1972 and 1974, respectively. Both species are now well established throughout the range of waterhyacinth in the southeastern U.S. and plans have been made to release *N. bruchi* near Sacramento, California.

Although *N. eichhorniae* populations have been established in Florida for 10 years and *N. bruchi* for 8, many persons involved in aquatic weed management are not familiar with these species. Although most do recognize the "waterhyacinth weevils" they are unable to distinguish between the two species. Further, outside of the scientific literature, no references are available to the aquatic weed manager that would provide information on the identification, biology, and ecology of these insect species. It is the purpose of this article to provide some of this information on these very important biological control agents.

Taxonomy and Identification

Beetles comprise the order Coleoptera of the class of animals known as insects. One of the most distinctive characteristics of this order is the arrangement and structure of the two pairs of wings. The front pair is usually very thick and leathery and folded over the back to cover the hind wings. The hind wings are usually thin and membranous, longer than the front pair, and folded under the front pair except when flying. The front pair of wings are called elytra (from the Greek for "a cover") and serve primarily as protection for the hind wings. The name of the order, from the Greek "koleos" meaning sheath and "pteron" meaning wing, refers to the elytra. The mouth parts of all beetles are constructed for chewing and include well developed mandibles. All beetles go through four distinct developmental stages in their life cycle which includes the egg, larva, pupa and adult.

Weevils comprise a family within the Coleoptera known as the Curculionidae or the snout beetles, referring to the elongation of the front of the head into a snout. The mandibles are situated at the end of the snout and the antennae usually arise at about mid-length on it.

Weevils in the genus *Neochetina* are classified into the subfamily Erirhiniae and the tribe Bagoini. (The implication of the name of the tribe, which is based on the genus *Bagous*, escapes me. It is derived from the Greek "bagoas" which means "a eunuch"). *Neochetina* is comprised of six species and their native range is primarily South and Central America. All are semiaquatic, are covered with a layer of very dense, water repellant scales, and feed on species of plants in the family Pontederiaceae.

The adults of *N. bruchi* and *N. eichhorniae* can usually be distinguished by the color and pattern of the scales covering the elytra. *N. bruchi* ranges in color from uniform tan or brown with no distinct markings to brown with a broad, crescent-shaped or chevron-like, tan band across the elytra. *N. eichhorniae* never has the tan band and is usually gray mottled with brown. The color pattern is associated with the scales and specimens may be difficult to identify if the scales are missing, or the specimens are dirty or wet. Both species have two short, shiny, dark lines on the elytra on

Continued on page 16

AQUATIC HERBICIDE BREAKTHROUGH

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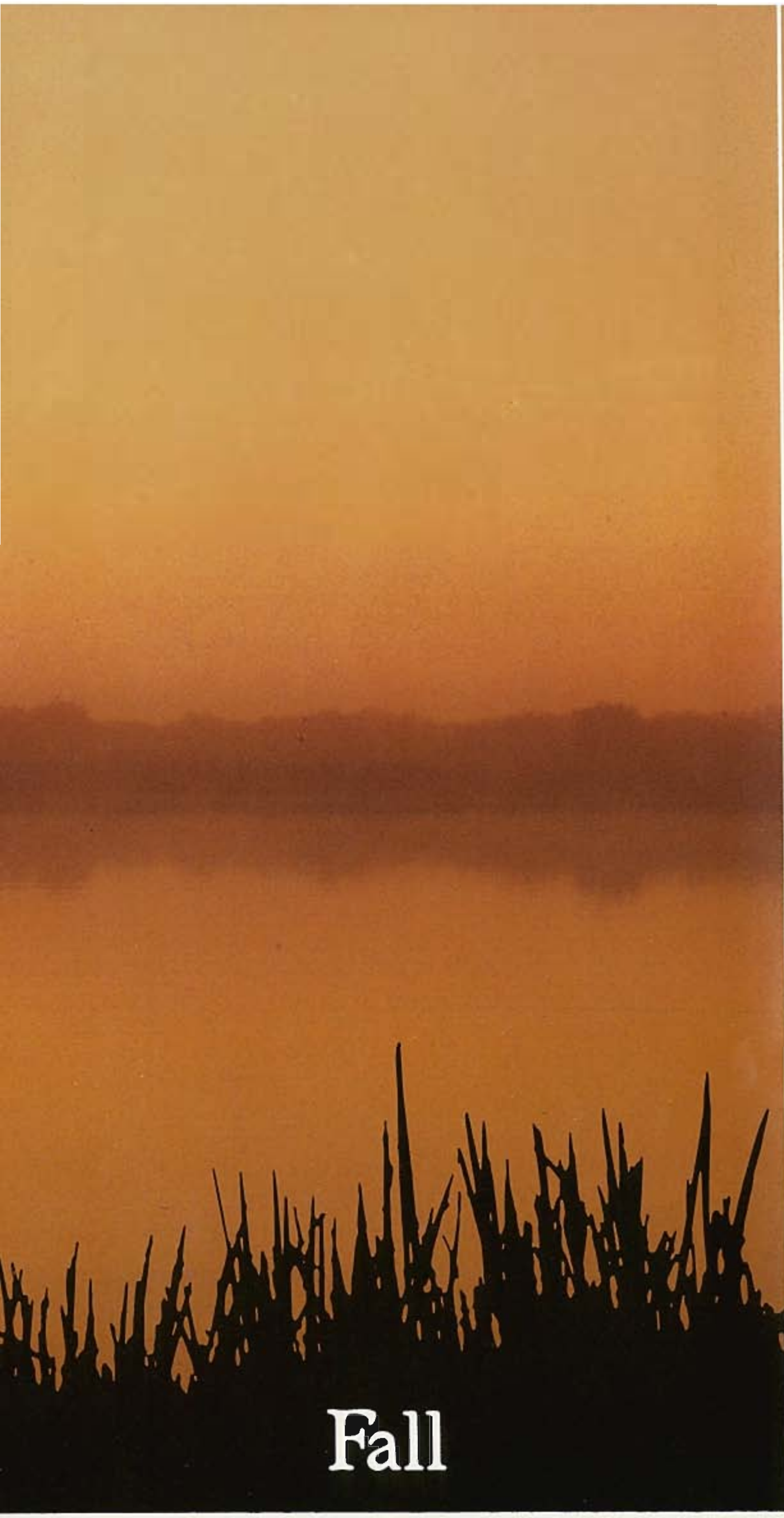

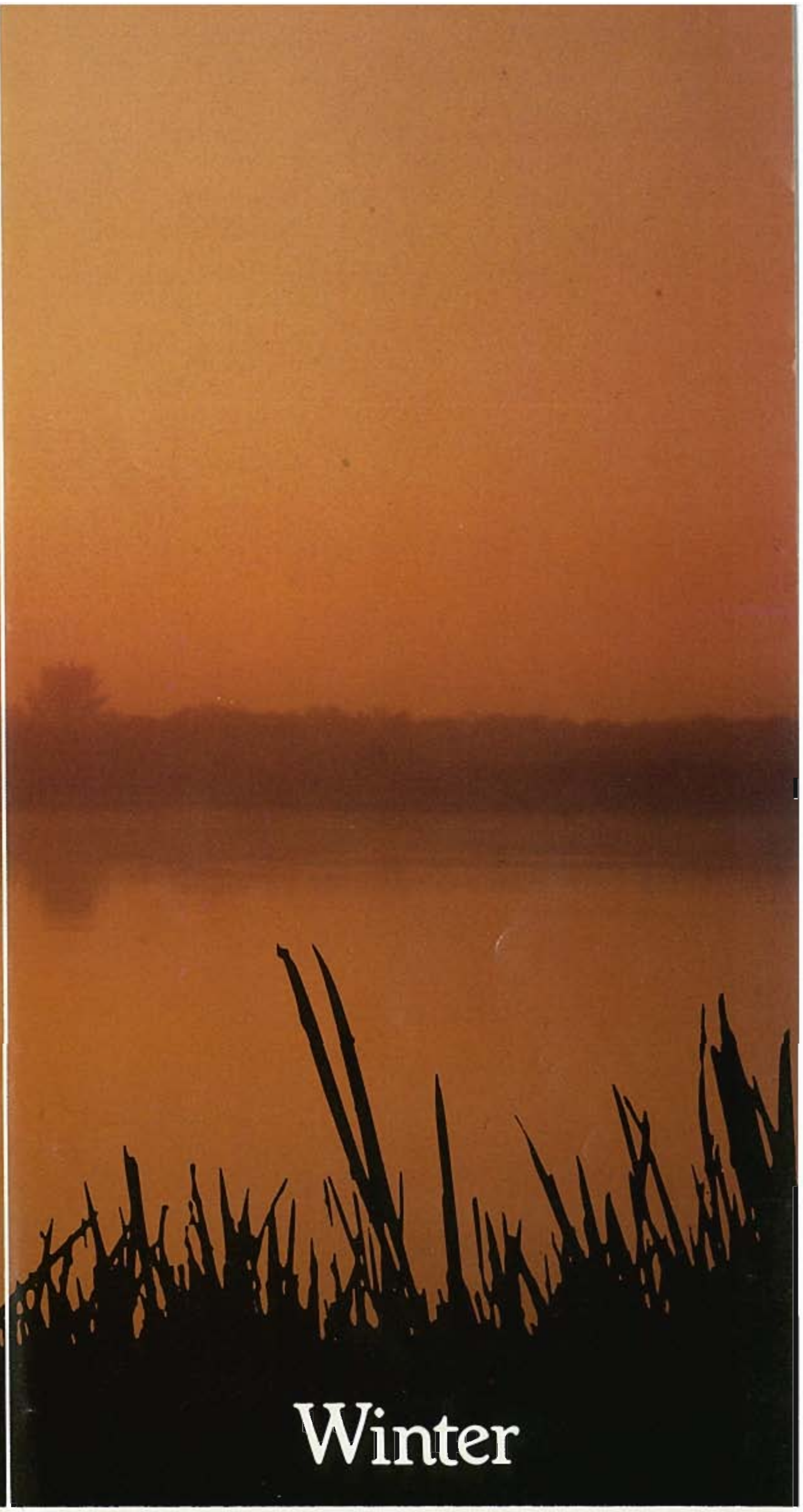

wildlife, or nearby trees and shrubs.

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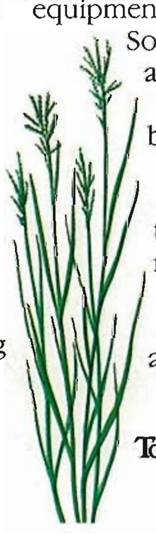
Pond weeds



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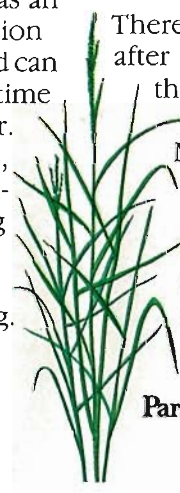
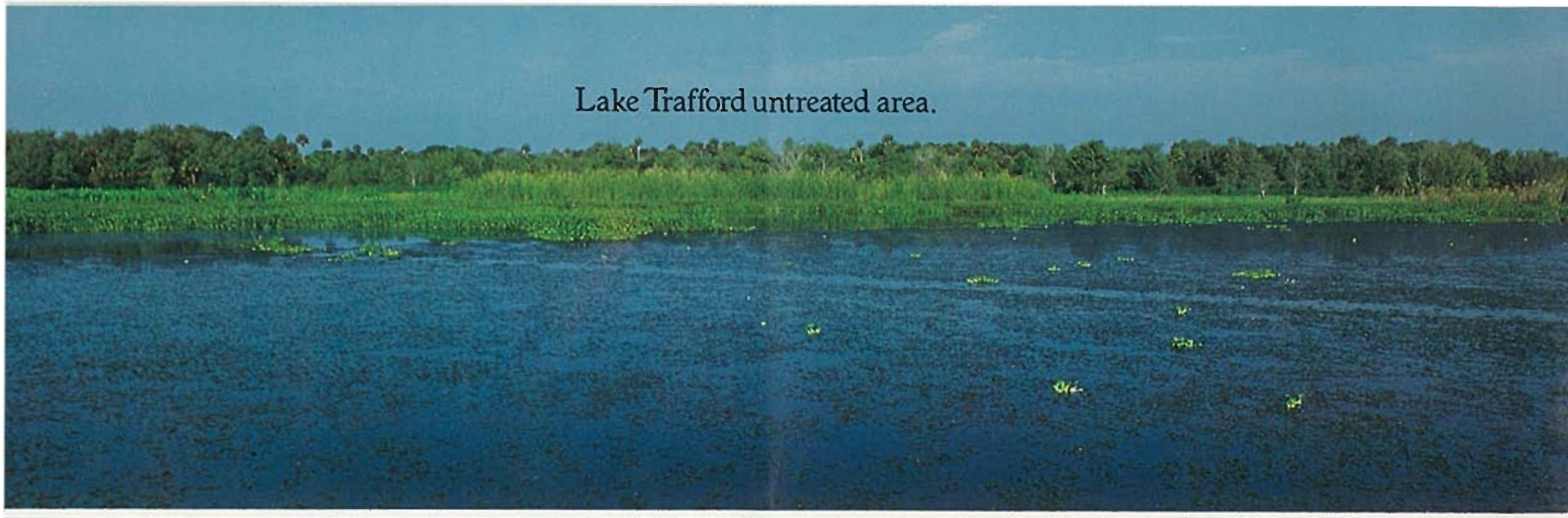
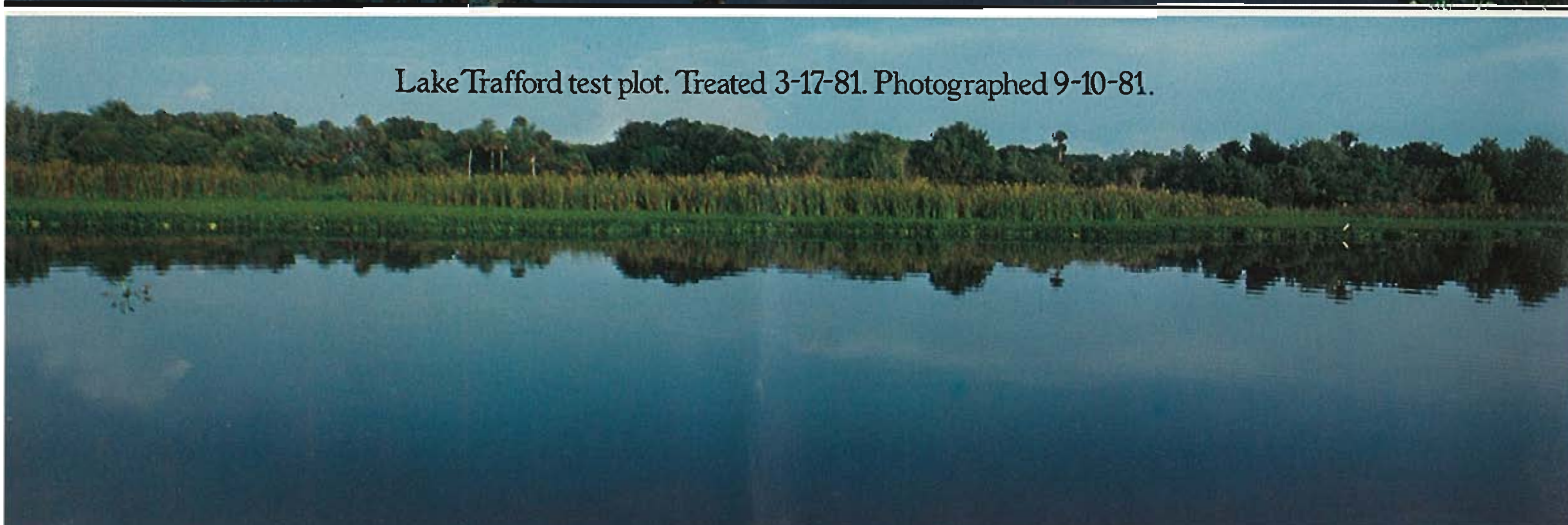


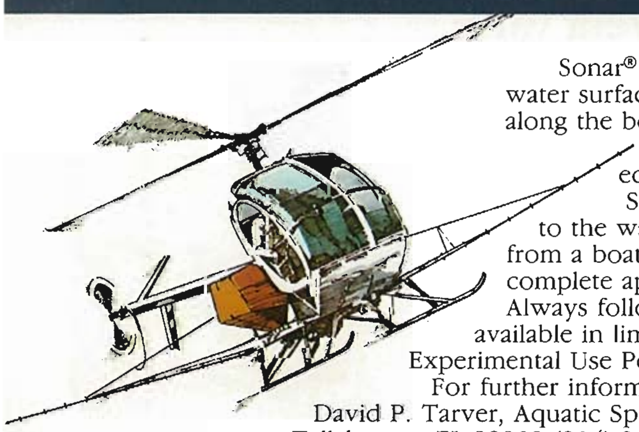
Paragrass



Lake Trafford untreated area.



Lake Trafford test plot. Treated 3-17-81. Photographed 9-10-81.



Sonar® aqueous suspension can be applied to the water surface or under the water surface or placed along the bottom of the water just above the hydrosoil. Any conventional application equipment can be used.

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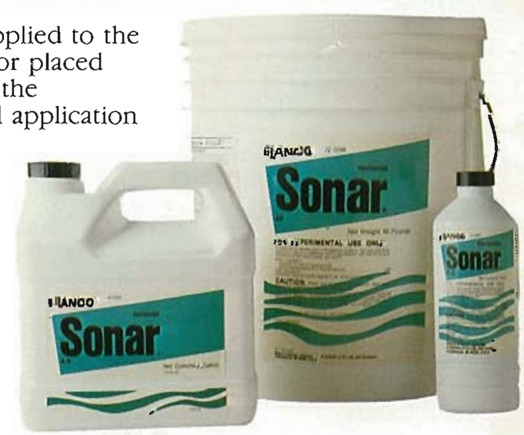

$ Herbicide vs. Grass Carp $

by
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Hydrilla is considered one of the most problematic aquatic plant species within Florida as evident by the amount of money, time and effort spent annually within the state on its control. Of the nearly 1 million acres of surface water present in lakes greater than 100 acres surveyed in 1980 by the Bureau of Aquatic Plant Research and Control, Florida Department of Natural Resources, only 3% were infested with hydrilla; even so $2,357,900.00 or an average of $187.64 per acre of hydrilla of Federal revenue was spent during that year. Since the distribution of 7,700 lakes (over 10 acres) within Florida is not evenly distributed among its counties, the cost of hydrilla control in many Florida counties is sizable. For example, in Orange County, its 67,000 acres of freshwater lakes had a 10.5% infestation of hydrilla in 1981 with the cost of treatment of $200,000.00 ($120,000.00 county funds, $80,000.00 federal matching funds). Of this amount, 55% was spent for herbicide while the remaining amount was for manpower, equipment and related costs. While the cost of hydrilla control from private individuals is unknown, it would surely add a significant amount to the overall cost of hydrilla control in Florida. Could expenditures of private, county and federal funds be reduced if grass carp were employed in hydrilla control programs?

A three year study conducted at UCF involving four central Florida lakes in the Orlando area was funded in 1979 by the Florida Department of Natural Resources to address this question. The primary design of the study was to compare grass carp (Clear Lake) to herbicide (Lake Mann) and to a grass carp / herbicide combination (Lake Orienta and Little Lake Fairview). Grass carp were stocked into Lake Orienta (18 fish / acre) at the start of the project (March, 1979). Herbicide was applied to Little Lake Fairview during the second year of the study. Grass carp were stocked into Clear Lake (25 fish / acre) in March, 1980; the beginning of the second year of study. After a baseline year, herbicide was applied to Lake Mann between April and September, 1980 (258 acres treated) and again in 1981. Herbicide application was made by the Orange County Pollution Control Department in Little Lake Fairview and by OCPCD and the City of Orlando in Lake Mann; the funds were provided by the Florida Department of Natural Resources. The herbicides used were Hydrothal 191 and Diquat with Cutrine. The herbicides were applied using conventional methods of application and dosage rates in order that Little Lake Fairview and Lake Mann would represent lakes treated chemically to control hydrilla. The grass carp were removed from Little Lake Fairview during the second year (94%) in October, 1980 and restocked with a larger number of grass carp in March, 1981. Little Lake Barton (24 fish / acre), Little Lake Fairview (33 fish / acre) and Lake Killarney (25 fish / acre) were stocked in March, 1981 at 20 fish / metric ton — fresh weight hydrilla. The Orange County Pollution Control Department and the Lake Killarney Homeowners Association supplied the grass carp for Little Lake Barton and Lake Killarney, respectively, while the grass carp stocked into Little Lake Fairview were supplied by the Florida Department of Natural Resources. These lakes were not treated with herbicide after the grass carp were stocked.

The grass carp eliminated the hydrilla in Lake Orienta within 6 months. Hydrilla biomass was suppressed, but not eliminated in Little Lake Fairview by the grass carp during the first year; elimination was not achieved with the grass carp / herbicide combination during the second year. In Clear Lake, the grass carp eliminated the hydrilla in May, 1981, approximately 14 months after the fish were stocked. The grass carp stocked into Little Lake Barton, Little Lake Fairview and Lake Killarney eliminated the hydrilla by October, 1981, 8 months after the March, 1981 stocking.

Table 1.
Cost of grass carp and herbicide in the six central Florida lakes.

	1979	1980	1981
Lake Orienta			
grass carp	$13,932.00		
$/acre	108.00	$ 54.00	$ 27.00
Little Lake Fairview			
grass carp	5,760.00		10,846.58
$/acre	72.00		135.58
herbicide		13,167.00	
application		1,743.00	
$/acre		186.38	
Clear Lake			
grass carp		50,850.00	
$/acre		150.00	75.00
$/mt-FW[1]		69.75	33.46
Lake Killarney			
grass carp			20,695.00
$/acre			88.44
Little Lake Barton			
grass carp			1,890.00
$/acre			142.11
Lake Mann			
herbicide		36,880.00	35,649.00
application		22,461.00	20,695.00
total		59,341.00	56,344.00
$/acre		243.20	230.92
$/mt-FW		127.07	505.33

[1]$/mt-FW = cost of treatment to reduce the annual mean biomass by 1 metric ton fresh weight hydrilla.

Hydrilla biomass was monitored on a monthly basis in Lake Orienta, Little Lake Fairview, Clear Lake and Lake Mann and bimonthly in Lake Killarney and Little Lake Barton; a submersed aquatic plant sampler was used to make vegetation collections. The use of a random sampling scheme utilizing parametric statistics provided a total lake hydrilla biomass value per month; these monthly values were used to determine the annual mean hydrilla biomass in metric tons fresh weight per lake (1

Continued on page 14

$ Herbicide vs. Grass Carp $ *continued from page 13*

metric ton = 2,200 lbs). The cost per treatment based upon the reduction of hydrilla (amount of control) was standardized by dividing the cost of the treatment (herbicide and/or grass carp) by the difference in the annual mean hydrilla biomass (in metric tons) between years, while the cost of treatment per acre was determined by dividing the treatment cost by surface acres.

The annual mean hydrilla biomass within Clear Lake for the baseline year of 1979 was 1500 metric tons fresh weight hydrilla. The annual mean biomass for the treatment year was 771 metric tons; this represents a reduction of 49% in hydrilla biomass or a reduction of 729 metric tons between the annual mean metric tons of hydrilla for the baseline year and the treatment (second) year. The cost to achieve the reduction (control) of hydrilla was $69.75 / metric ton fresh weight hydrilla ($50,850.00 for grass carp divided by 729 metric tons). The cost per acre in Clear Lake was $150.00, Table 1. The annual cost of hydrilla control in Clear Lake per acre was determined by dividing the cost of the fish by the number of years the fish were in the lake, thus after two years the annual cost was $75.00 / acre, after three years, $50.00 / acre and so on. Since the amount of hydrilla in Clear Lake was reduced by 760 metric tons fresh weight hydrilla between 1980 and 1981, Table 1, the treatment cost becomes $33.46 / metric ton fresh weight hydrilla ($50,850.00 for the grass carp divided by 2 years = $25,425.00 divided by 760 metric ton fresh weight hydrilla = $33.46 / metric ton).

For comparison, the amount of reduction in hydrilla in Lake Mann by herbicide between 1979 and 1980 was $127.07 / metric ton fresh weight hydrilla ($59,341.00 for herbicide divided by 467 metric tons fresh weight hydrilla = $127.07 / metric ton). This is nearly twice the cost of the treatment with grass carp in Clear Lake during 1980. The cost of hydrilla control in Lake Mann during 1981 was $505.33 / metric ton fresh weight hydrilla, Table 1, or nearly 5 times greater than the cost of treatment with grass carp in Clear Lake during 1980 and nearly 15 times more than the cost for Clear Lake in 1981. While the cost per acre using grass carp decreases exponentially through time, herbicide treatment costs per acre tend to remain static (or increase with inflation) with time. This is due to the fact that even though the biomass of hydrilla can be reduced between years when herbicide is used, the distribution and regrowth of hydrilla tends to remain the same year after year; this requires the same acreage to be treated annually. In Lake Mann, the hydrilla biomass was reduced 84% over two years, yet the distribution of hydrilla remained the same. If one extends the annual cost of treatment in Clear Lake (grass carp) and Lake Mann (herbicide) over a 10 year period, the average cost for Clear Lake is $5,085.00/ year and $57,842.50 / year for Lake Mann. The total cost for 10 years of hydrilla control in Clear Lake would be $50,850.00, the initial cost of the grass carp, while the treatment cost for Lake Mann would be $578,425.00 assuming no increase or decrease in the annual inflation rate.

The cost of the herbicide / grass carp combination was determined using the 1979 and 1980 data for Little Lake Fairview. Since no baseline data was available for grass carp alone, the cost of the grass carp (1979) was added to the cost of the herbicide (1980) and the amount of hydrilla reduction was determined between 1979 and 1980, Table 1. In this case, the cost of hydrilla control was $143.57 / metric ton fresh weight hydrilla; a value substantially higher than when grass carp were used alone, but not significantly greater than the cost of herbicide used without grass carp.

The average cost of grass carp to eliminate hydrilla within one year was $125.43 / acre (mean cost for grass carp stocked into Lake Orienta, Little Lake Fairview, Little Lake Barton and Lake Killarney). Grass carp should be stocked per biomass in large lakes where cost is a vital concern since fish insufficiently stocked to obtain control within two years would prove to be costly, if not more so, than herbicide. In small impoundments where the number of fish required is minimal, the fish could be over-stocked with little financial risk. The average number of grass carp stocked in the study lakes was 25 fish / acre.

Of the 7,000 acres of hydrilla infested waters in Orange County in 1981, approximately 6,000 acres are suitable for grass carp. To stock these waters with 25 fish / acre would cost $525,000.00 ($3.50/1 lb. grass carp), saving $171,428.00 per year on herbicide treatments. The expense of the grass carp would be redeemed in three years, with a savings over the next 7 years of $1,199,996.00 ($719,998.00 in county revenue) over herbicide treatments. Statewide, the savings would approach $2,000,000.00 per year over herbicide treatment costs from federal sources assuming the grass carp could be used in 85% of Florida's infested waters. This savings would be greater if the annual inflation rate was considered.

The author would like to thank the Florida Department of Natural Resources, Bureau of Aquatic Plant Research and Control, and the Orange County Pollution Control Department for providing information used in this article.

AQUA-VINE

DNR Issues Memorandum on Section 18 — Scout™

On October 16, 1981, an emergency exemption was requested pursuant to Section 18 of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) by Doyle Conner, Commissioner of the Florida Department of Agriculture and Consumer Services, for the use of the chemical glyphosate to control emergent aquatic weeds. The filing for the emergency use was justified to prevent severe flooding and the resultant damage to property, agriculture lands, human health and loss of life. The Environmental Protection Agency (EPA) granted a specific exemption on April 1, 1982 for the use of glyphosate (EPA registration number 524-326) to control emergent weeds. The product Roundup®, produced by Monsanto Corporation is not and will not be permitted for use in aquatic systems. The glyphosate formulation which received the Section 18 emergency exemption will be marketed as the Monsanto Product Scout™.

The active ingredient in Scout™, glyphosate, is identical to that in Roundup; however, Scout™ does not contain the surfactant. Therefore, to achieve control on emergent plants, Monsanto is recommending the use of the surfactant X-77® produced by the Chevron Corporation. Scout™ will contain 4 pounds of the acid, glyphosate per gallon compared to 3 pounds in Roundup®. Scout™ will become available in early June 1982.

Fourteen thousand five hundred gallons of Scout™ will be made available by Monsanto to treat 19,400 acres at a rate of 4½ to 7½ pints per acre. Since the request for a Section 18 for glyphosate was made for use in emergency flooding situations, and since the specific exemption was granted from the Code of Federal Regulations where Section 166.1 requires an emergency situation to exist with no alternative methods of control available, and since only 19,400 acres can be treated with Scout™ in Florida, the Department of Natural Resources will permit the use of Scout™ under the Section 18 label for emergency situations only. These areas will be determined by the Department and will include rivers, canals, and ditches with standing or flowing water as well as lake and pond outfalls and inflow areas where emergent plants could cause water to back up and create flooding conditions. The EPA has specifically excluded glyphosate from streams on Eglin Air Force Base, Atlantic Seaboard Rivers, and their immediate tributaries, and from use within one mile of domestic water intakes. Any permitted uses of Scout™, as with all other aquatic herbicides, must be reported to the Department of Natural Resources on the quarterly report forms which have been in effect since April 9, 1982.

Please refer any questions regarding use restrictions of Scout™ to Jeff Schardt at (904)488-5631.

Roundup® is a registered trademark of Monsanto Company
Scout ™ is a trademark of Monsanto Company
X-77 ® is a registered trademark of Chevron Company

IFAS Aquatic Weed Short Course

An IFAS Aquatic Weed Short Course will be held at Reitz Union on the University of Florida Campus, Gainesville, Florida, June 21-25. Pre-registration is requested but not required. The pre-registration fee will be approximately $40.00.

Topics to be covered during the training will include: biological, mechanical and chemical control; plant identification and biology; herbicide application equipment calibration; aquatic herbicides; aquatic weed harvesting equipment; limnology and more. Contact Dr. Vernon Vandiver, Jr., AREC Ft. Lauderdale, 3205 S.W. College Avenue, Ft. Lauderdale, FL 33314 (305)475-8990.

"Tour" Package to Las Vegas

Tom Wiley is looking for anyone in the south Florida area who may be interested in participating in a "Tour" package to the A.P.M.S. Convention in Las Vegas July 11-14. 15 or more parties qualify for tour rates. For further information contact Tom Wiley at 305/564-5981 (home) or 305/472-5251 (office).

Call for Papers

As you are aware, the FAPMS annual meeting is only a few months away. There has never been a better opportunity to become active and participate in the society. Share your experiences, new control methods, new techniques, research projects and other bits of wisdom with your fellow society members by giving a presentation at the annual meeting. If you have never presented a paper at the meeting, this is your year.

Please send the title of your presentation to: Michael J. Mahler, 3033 Huntington Woods Blvd., Tallahassee, Florida 32303.

either side of the mid-line. This short line is actually a tubercle or ridge and its position varies between the two species. On *N. bruchi* the tubercles are situated very near mid-length. Although the position of the tubercles is more variable on *N. eichhorniae* they are usually situated further forward, in front of mid-length. A more subtle character separating these two species concerns the lines (striae) which run lengthwise and nearly parallel to one another on the elytra. These striae are actually shallow grooves. On *N. bruchi* the striae are relatively fine whereas on *N. eichhorniae* they are relatively coarse. This gives *N. bruchi* an overall smoother textural appearance than *N. eichhorniae*.

Other characters exist which may be more reliable but are generally not useful to a non-entomologist. For more information on taxonomy and identification of the adults see the papers by R. E. Warner (1970. Proc. Entomol. Soc. Wash. 72 (4):487-496), C. J. DeLoach (1975. Coleop. Bull. 29(4):257-265), and C. W. O'Brien (1976. Ann. Entomol. Soc. Am. 69(2):165-174).

The eggs, larvae, and pupae of both species are very similar and virtually indistinguishable from one another. Identification of the immature stages is difficult, even for an expert.

Eggs are whitish, ovoid, and about ¾ mm (ca. 1/30 in.) in length. Since they are embedded in the plant tissue, they can usually only be found by dissecting the plant under a microscope.

Larvae are white or cream-colored, with a yellow-orange head. They have no legs or prolegs, only enlarged swellings with setae (small hairs) where the legs should be. The posterior end of the abdomen is blunt and a pair of spiracles (breathing tubes) project upward, somewhat spur-like, on the last abdominal segment. These spur-like spiracles presumably allow the larva to obtain oxygen by inserting them into the plant tissue. When the larvae first emerge from the egg they are very small (ca. 2 mm in length) and cylindrical in shape. The fully-grown third instar larva is somewhat grub-like, C-shaped, and ca. 8-9 mm in length.

Pupae are white and resemble the adults. The pupa is enclosed in a cocoon formed among the lateral rootlets and attached to the main root axis below the water surface. These appear as small balls or nodules ca. 5 mm in diameter on the roots usually near the rhizome.

Biology and Life History

Eggs of both species of *Neochetina* are deposited directly in the plant tissue. The female chews a hole into the lamina or petiole in which to lay eggs. *N. eichhornia* deposits only one egg in each hole whereas *N. bruchi* deposits several. Either species may also place the eggs around the edge of leaf abrasions created by the feeding of the adults. DeLoach reported that *N. bruchi* preferred to oviposit in leaves with inflated petioles and especially those at the periphery of the plant while *N. eichhorniae* preferred the tender central leaves or the ensheathing stipules at the leaf bases. We have found that eggs of *N. eichhorniae* are rare in the youngest leaves and are usually found in those of intermediate age. Eggs are most prevalent in the basal portion of the petioles where the stipules are somewhat open and a space is available for the adults to congregate.

The eggs hatch within 7-10 days at 75°F. The first stage (instar) larvae are very small with a head diameter of ca. ⅓ mm (1/75 in.). They begin to burrow under the epidermis and work their way toward the base of the leaf. They feed and grow and shed their skin twice to pass through a total of three larval instars. The first molt occurs when the larvae are about 10 days old and the second about 2 weeks later. As they grow larger the galleries or feeding burrows become larger. Third instars are generally located at the petiole bases and may enter the stem (rhizome) and excavate small pockets at the point of insertation of the leaf. They occasionally burrow up the stem to enter the base of younger petioles and sometimes reach the stem apex and destroy the apical bud. The larval period probably requires 30-45 days with *N. bruchi* developing somewhat faster than *N. eichhorniae*.

The fully developed larvae burrow out of the stem and move to the upper root zone just under the surface of the water. They cut off the small lateral rootlets and form a spherical parchment-like cocoon around themselves. This cocoon is attached to one of the roots. Curiously, at the point of attachment, the larva chews a notch into the root. This notch supposedly functions in gas exchange between the hollow inside of the cocoon and the vascular tissue of the plant. After the cocoon is formed the larva molts a third time and becomes a pupa. This is the inactive stage when the transition from larva to adult occurs. It is not known with certainty how long this stage lasts, but best estimates indicate about 30 days.

We have observed a few adults emerging from the cocoon but we are not certain of the mechanics involved. The emerging adults appear to split the cocoon, push the opening wider with their legs and pull themselves out through the split. Once they are out, they climb up onto the emergent leaves of the plant to feed and mate. The female weevils begin to lay eggs within a few days after emerging from the pupa and most are deposited within the first week. A single female *N. bruchi* will deposit up to 300

A body of water is a living thing...
A delicate balance of plant and animal life. A varied assortment of creatures, many too tiny to see. A place to make peace with the world, and enjoy the wonders of nature.
But all this can change quickly. A slight shift in the environment and a tiny group of plants may suddenly burst into a teeming mass of choking weeds and slime. The effect is dramatic, as fish and other life forms struggle for survival in this hostile new world.
How to deal with these troublesome intruders? How to be sure that the delicate creatures already there may continue their existence unaffected?
The choice is Pennwalt Aquatic Herbicides. To quickly restore the natural balance. Without harming wildlife. Or human visitors.
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eggs but *N. eichhorniae* deposits only about 60. DeLoach noted that about 90% of the eggs are deposited within a month after the female emerges although the adults may live over 9 months. For further details on the biology of these species, see the articles by C. J. Deloach and H. A. Cordo (1976. Ann. Entomol. Soc. Amer. 69:643-652 and 1976. Jour. Aquat. Plant Manag. Soc. 14:53-59).

Both species of *Neochetina* tend to be very host specific, that is, their diet is relatively restricted to waterhyacinth and the larvae are generally unable to develop on other plant species. In Florida, however, *Neochetina eichhorniae* adults have caused minor feeding damage to ornamental species of *Canna*, although this damage is generally of no consequence and certainly not economically important. Although Gary Buckingham (USDA, Gainesville) has found that the adults will also feed to some extent on pickeralweed (*Pontederia*), thus far the larvae are not known to feed on anything other than waterhyacinth.

Population Biology

Two distinct peaks in the populations of *N. eichhorniae* appear to occur per year in north Florida. Larvae, pupae, and adults over-winter in waterhyacinth stands although the numbers are very low. During cold periods the larvae burrow deep within the stem to several centimeters below the water. If plants survive during the winter, adults and pupae can usually be found on them. In late March or April an increase in the number of adults becomes apparent. This is followed by a dramatic increase in the number of larvae by April or May and in the number of pupae in May or June. By late June the number of adults begins to increase rapidly and by August the adult population reaches its highest peak of about 250 per square meter (three to four per plant). This is followed by a second larval peak in September and a second peak of pupae in October. All stages decline in number rapidly during the latter part of the year and by the onset of the first frosts (usually mid-December) populations are again very low.

It is curious that this population decline is so dramatic during the fall. It is a very predictable, annual occurrence. In mid-August 1980 in southern Louisiana tremendous numbers of adult *N. eichhorniae* congregated at lights around buildings and became somewhat of a nuisance for a while. When we investigated we found that the weevils were being attracted tp mercury vapor lamps and that this was happening in areas very near massive acreages of waterhyacinth. We would speculate then, that this was a dispersive phase in the population cycle associated with the annual decline in the population density. Whether this is triggered by the presence of large populations, by photoperiod, by deterioration of the plants, by temperature, or by other factors, we don't know.

There have been no thorough studies done in the U.S. on the natural enemies of *Neochetina* although we have found a small mymarid wasp (*Patasson* sp.) which parasitizes the eggs. These have been found both in Gainesville and Fort Lauderdale but the percentage of the eggs parasitized is very small.

Continued on page 19

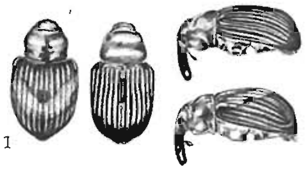
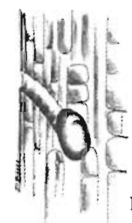


FIG 1



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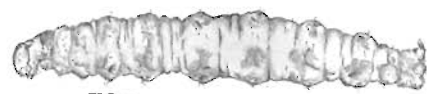

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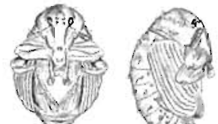
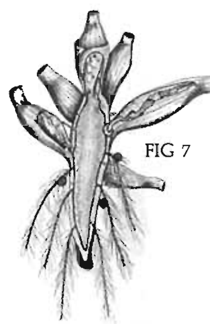


FIG 4

FIG 5

FIG 6



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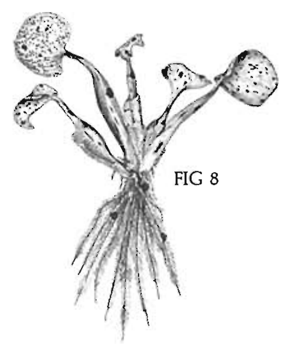

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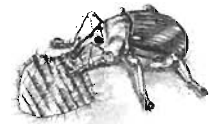
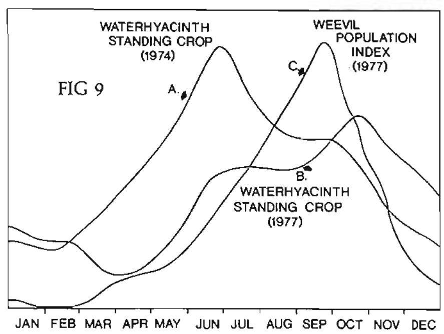


FIG 10



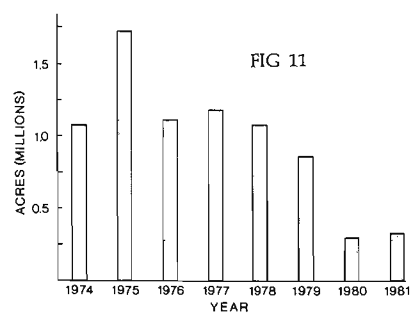


FIG. 1. *A comparison of dorsal and lateral views of* NEOCHETINA BRUCHI *(left and bottom) and* N. EICHHORNIAE *(right and top) adults. (This and all following illustrations are by B. Benner.)* **FIG. 2.** *A stylized illustration of a section of a waterhyacinth petiole split open to show the hole made by a female weevil by chewing into the tissue with her snout in order to create an oviposition site. An egg is shown within the tissue at the end of the hole.* **FIG. 3.** *The mature third instar larva of* NEOCHETINA BRUCHI. *Note the blunt tail end with the dorsal spur-like spiracles, and the lack of legs. The head is yellowish orange and the body is whitish or cream-colored.* **FIG. 4.** *Ventral (left) and lateral (right) views of a* NEOCHETINA BRUCHI *pupa which has been removed from its cocoon.* **FIG. 5.** *A* NEOCHETINA BRUCHI *cocoon formed among the lateral rootlets and attached to the main axis of a waterhyacinth root.* **FIG. 6.** *An adult* NEOCHETINA *sp. emerging from the cocoon.* **FIG. 7.** *A cutaway view of a waterhyacinth stem showing larval galleries within the petioles and a larva in an excavated pocket at the point of insertion of a leaf petiole (middle right). Also shown are the small, ball-like cocoons on the roots in spatial relationship to the rest of the plant.* **FIG. 8.** *The typical appearance of a waterhyacinth plant heavily damaged by* NEOCHETINA *adults and larvae.* **FIG. 9.** *An example of data from a site in north Florida showing the shift in the seasonal abundance of waterhyacinth which occurred after* NEOCHETINA EICHHORNIAE *was introduced in 1974 (compare lines A and B). Also shown is the pattern of season abundance of the adults as evidenced by the number of feeding lesions on the leaves during 1977 (line C).* **FIG. 10.** *An adult* NEOCHETINA BRUCHI *shown next to a feeding lesion on a waterhyacinth leaf.* **FIG. 11.** *Data from Louisiana showing the trend over the past several years in the total statewide acreage of waterhyacinth. Weevils were first released in Louisiana in 1974. Data were gathered by the Louisiana Wildlife and Fisheries Commission and provided by the courtesy of the U.S. Army Engineers Aquatic Plant Control Research Program, Vicksburg, MS.*

Watermilfoils *continued from page 4*

water currents to new habitats. In addition to these natural dispersal agents, watermilfoils may be transferred by boats and by aquatic plant collectors.

Control of *M. spicatum* in Florida primarily is accomplished by the application of 2,4-D. Biological control methods including the use of parasitic insects and herbivorous fish are being tested. In 1975 grass carp (*Ctenopharyngodon idella*) were used as a biological control for watermilfoil in Deer Point Lake and subsequently brought the infestation under control. However, the carp prefers other aquatic plants over *M. spicatum*, and as a result has decimated Deer Point Lake's native aquatic plant populations as well. Currently no single method of control does result in the total eradication of Eurasian Watermilfoil in Florida. Therefore, early detection, integrated control methods and continued research are necessary for coping with this serious aquatic weed problem in the state.

The Waterhyacinth Weevils *continued from page 18*

Effects of Neochetina spp. on Waterhyacinth

Damage caused to waterhyacinth by the adults of both species of weevils is very distinctive and conspicuous. Adults move their snout across the surface scraping off a line of epidermis with their mandibles. As they finish one line they move slightly and begin another parallel to the first. They continue feeding in this fashion until a small rectangular area of epidermis is removed leaving a very distinctive lesion or feeding scar. These vary in length depending upon the time spent feeding. A characteristic pattern of parallel ridges is often apparent within the scar. Feeding occurs primarily on the lamina of the leaf and *N. eichhorniae* adults prefer the youngest leaves.

As the larvae burrow within the petioles, a great deal of damage is done to the leaf. The feeding galleries become waterlogged and necrotic and evident as long, brown lines visible on the outside of the petiole. When several of these galleries converge at the petiole base, the extensive damage to the vascular tissues may cause the leaf to wilt. In extreme cases the petiole breaks or rots through and is severed from the stem. In less extreme cases the larval gallery collapses causing a sunken line of scar-like tissue.

As the larvae mature and enter the stem, the damage caused is superficial. However, when many larvae are present this damage may become substantial and cause the stem to fragment and the shoot to fall apart. When large numbers are present, the chance of one reaching the apical bud increases. If it is destroyed the shoot dies. The entry of the larvae into the stem seems to be accompanied by the entry of microbial organisms. These cause the stem to soften, rot and turn black.

The effects of the weevil damage are rarely visible as a sudden collapse of the waterhyacinth population. Subtle changes occur which are difficult to observe over the short term. The first effect is a decrease in the size of the plants. In 1974, before the weevils were released at one study site, the plants attained average heights of 100 cm. or more. As the weevil populations increased, the plants became progressively smaller over the years and in 1978 the average height failed to exceed 65 cm. The second effect is an inhibition of the growth of the mat. Areas that were cleared remained clear longer. Annual fluctuations in plant density were dampened and numbers remained more stable. The plants would not regrow into holes left in the mat when we removed samples. The rapid period of spring growth was delayed and biomass tended to peak in the fall rather than late spring. Peak standing crop declined from 2.5 kg to about 1.5 kg. (dry weight per square meter). Waterhyacinth coverage of this study site declined from over 90% in 1974 to about 25% in 1980.

Much more dramatic changes have occurred in some areas. By 1976, Dr. David Perkins was able to demonstrate that waterhyacinth had disappeared at some sites in southern Florida. In Australia, Mr. Tony Wright of the Commonwealth Scientific and Industrial Research Organization has reported on the rapid collapse of waterhyacinth populations following establishment of *N. éichhorniae* in several parts of Queensland. Dr. Al Cofrancesco of the U.S. Army Corps of Engineers Aquatic Plant Control Research Program has reported on the dramatic reduction of waterhyacinth acreage in Louisiana. His data are based on annual surveys conducted by the Louisiana Wildlife and Fisheries Commission and was provided through the courtesy of James Manning. According to these data, the acreage of waterhyacinth in the state averaged about 1.2 million acres prior to the 1974 releases of *N. eichhorniae*. About 4 years after the release of the weevils the acreage began to decline and in 1979 and 1980 it was down to less than 350,000 acres. Because biological control does not occur rapidly the effects are not easily documented. Evidence now indicates that the biological control of waterhyacinth has become effective.

Conservation of Neochetina *spp.*

At the time *N. eichhorniae* was first released there was tremendous interest and support by federal, state, and local agencies. Everyone seemed to want weevils for release and there was a great deal of cooperation involved in the dissemination of these insects throughout the Southeast. As a result, *N. eichhorniae* is now present virtually throughout the range of the waterhyacinth in the southern states. It is disturbing that after the insects were released and became established there was no similar interest to conserve the established populations.

Because the eggs, larvae, and pupae are relatively immobile and within or attached to the plant, they are unlikely to move to other plants if the one they are in should die. The adults are the only stage capable of moving more than a few feet. When extensive acreages of waterhyacinth are treated with relatively fast acting herbicides, all of the immature stages of the insects are eliminated along with the plants. When plant regrowth occurs, few insects are present to suppress it and reinvasion occurs rapidly. A few adult weevils may find these plants and begin to feed and lay eggs but, because the plants grow so quickly and the weevil population so slowly, the plants are again a problem before sufficient numbers or weevils are present to have an effect. It then becomes necessary to use the herbicide again and again the insects are eliminated. This repetitive cycle is the primary reason that the weevils have not been effective at highly managed sites.

One must be pragmatic however, and recognize that control operations must be maintained and that immediate needs preclude "waiting" for the insects to be effective. The conflict between the need to conserve biocontrol agents and the need to control aquatic weeds is problematic and only beginning to be examined by way of research. Herbicide application may be timed so as to minimally interfere with the insects. Slowly acting compounds may be used which would allow a majority of the insects to complete development before the plants die. A pattern of herbicide application may be implemented which would leave some of the insect populations available to attack subsequent regrowth. Growth retardants may be used which would slow plant growth sufficiently for the insects to overtake them. Many possible alternatives must be examined if waterhyacinth control is ever to become a truly integrated strategy. It will require a great deal of time and research to fully investigate these alternatives. For now, however, the best way for the aquatic plant manager to promote biological control of waterhyacinth is to protect some plants from control operations and thereby provide a reserve of insects for infestation of subsequent regrowth.

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