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Project Summary

Ecological Impact of Integrated Chemical and Biological Aquatic Weed Control

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The final report summarized herein presents results of a four-year study of the ecological impacts of chemical, biological, and integrated methods of aquatic weed control. Biological and water quality changes occurred as abundance of macrophytic vegetation was altered by natural factors or managment practices. Macrophyte abundance strongly influenced the structure of communities, and it was concluded that environmental effects of plant management programs are determined more by the amount of vegetation controlled than by management technique. Also, changes in lake hydrology and rates of nutrient loading appear to be more important as determinants of lake water quality than macrophytes. Research needs for evaluation of effects of weed control on aquatic systems are identified.

This Project Summary was developed by EPA'S Environmental Research Laboratory, Gulf Breeze, FL, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Aquatic weed infestations in lakes of the United States and other countries have increased dramatically during the last several decades because of cultural eutrophication and the introduction of exotic plants, such as hydrilla *(Hydrilla verticillata)* and eurasian watermilfoil *(Myriophyllum spicatum)*. These weed infestations have severely restricted many domestic, agricultural, industrial, and recreational water uses, thus increasing demand for weed control. Because water is becoming an increasingly valuable resource, many user groups, concerned about the impact of aquatic plant control techniques on the aquatic environment, are expressing concern for development of effective, yet environmentally safe, aquatic plant management programs.

Formulation of aquatic plant management programs for different aquatic systems, however, is extremely difficult. While scientists believe aquatic plants are important for healthy populations of fish and wildlife, and for proper functioning of aquatic ecosystems, little quantitative data are available for determining how many aquatic plants are necessary. Also it is very difficult to accurately assess the level of aquatic plant abundance that constitutes a weed problem. The short- and long-term economic, sociological, and environmental impacts of different control techniques are likewise difficult to assess. For example, aquatic herbicides are used by many local, state, and federal agencies to control aquatic macrophytes. Although the herbicides are tested and eventually registered for use by the U.S. Environmental Protection Agency, some other agencies and some segments of the public believe that the long-term impacts of chemical control are not sufficiently known to justify the use of herbicides. Also, since many aquatic herbicides are not effective over long periods of time, chemical control materials costs are very high. Florida alone spends over $20 million annually for chemical control programs. The grass carp *(Ctenopharyngodon idella)* is an effective and economic biological control organism, but these fish consume all macrophytic vegetation when stocked in sufficient numbers. Research studies on grass carp have provided conflicting and often confusing results, and biologists disagree about the grass carp's ultimate impact on the aquatic environment. These research conflicts have led to the banning of the grass carp in many areas, including Florida.

Because fresh waters are used for a variety of purposes, the costs and benefits to various user groups must be considered. In Florida, freshwater sport-fishing is a very large aquabusiness, generating over $525 million annually. While fishermen generally prefer vegetation, homeowners generally want weed-free shorelines, and, quite often, weed-free lakes. Because of their different desires, these groups are often in direct conflict.

This study was initiated to provide quantitative information on the influence of the density of aquatic plants and the impact of chemical and biological (grass carp) management techniques on the aquatic environment. The study consisted of three separate projects in Florida. Orange Lake, a large lake with an abundance of macrophytes, was studied to determine the effect of naturally occurring fluctuations in vegetation and the effect of different vegetation types on the aquatic environment. Orange Lake was not treated for weed control. Lake Pearl, a small lake (23.5 ha) with an abundance of hydrilla, was studied to determine if chemical and biological control techniques could be integrated to provide long-term vegetation management without removing all vegetation. At Lake Pearl, herbicides and grass carp were studied to determine the impact of integrated management on the aquatic environment. Finally, pond studies were conducted to determine the environmental impact of different aquatic plant management techniques at different degrees of weed management. Effects of several herbicides and the grass carp were determined.

Experimental Procedures

Limnetic and littoral stations were established in Lake Pearl and Orange Lake. Line transects were run monthly at the lakes and at 24 artificial ponds at Welaka to determine frequency of occurrence and the percentage of the cover for weed species. Water quality was monitored and related to density of weeds and weed-control treatments. Water quality parameters measured were: dissolved oxygen, pH, carbon dioxide, bicarbonate, carbonate, color, turbidity, specific conductance, potassium, calcium, magnesium, chlorophyll, pheophytin, orthophosphate, total phosphorus, and total nitrogen. Periphyton was analyzed by use of glass-slide samplers; benthos, by use of a Ponar dredge; plankton, by vertical hauls of a Wisconsin plankton net; and standing crop and biomass of fishes, by blocknet sampling. A pulsed DC current electrofishing boat was used triannually to collect bluegill *(Lepomis machrochirus)*, redear *(Lepomis microlophus)*, warmouth *(Lepomis gulosis)*, largemouth bass *(Micropterus salmoides)*, and chain pickerel *(Esox niger)*. Stomachs of the fishes were analyzed for food content. Migration of largemouth bass and grass carp in Lake Pearl was followed by telemetry.

The Lake Pearl study was designed to assess the feasibility of an integrated approach to aquatic weed control utilizing herbicides and grass carp. Where herbicides are used extensively for aquatic vegetation control, several treatments are required annually. Grass carp eliminate submersed macrophytes when stocked in numbers large enough for weed control. An attempt was made to develop a cost-effective method for vegetation management without elimination of all submersed macrophytes by integrating biological and chemical control methods.

Before initiation of control measures, total weed biomass in Lake Pearl was estimated with the U.S. Army Corps of Engineers' biomass sampler. Because hydrilla comprised over 99% of total vegetation biomass, the lake was considered to contain a monoculture of that species. Herbicides used were a mixture of diquat and copper, a mixture of endothall and copper, and endothall alone. Grass carp were stocked at the rate of 12 fish/ha.

In Orange Lake, hydrilla was dominant between July and November, while coontail *(Ceratophyllum demersum)* and southern naiad *(Najas quadalupensis)* were dominant at other times. Spatterdock *(Nuphar luteum)* and maidencane *(Panicum hemitomon)* and 17 other macrophytic species were also present, and natural variation in plant numbers, water quality, and composition of plankton, benthos, epiphyton, and fishes were described.

Similar studies were done on 24 ponds at Welaka, Florida. In addition to untreated controls, the ponds were treated with fertilizer, grass carp, or the herbicides endothall, diquat, 2, 4-D, o glyphosate.

Conclusions

Orange Lake, Lake Pearl, and Welaka pond data indicate that hydrilla can rapidly colonize both the littoral and pelagic lake regions under optimal limnological conditions. In shallow water systems, such as Lake Pearl, this can eliminate the ecotone between open water and vegetated areas. Dense vegetation, therefore, alters water quality and native plant and animal communities. Whether these changes are good, bad, or indifferent depends on the criteria used by various user groups to judge the quality of the lake.

Our study, like many others, demonstrates that aquatic macrophytes may alter water quality. In Lake Pearl, where macrophyte abundance was initially high, reduction in average pH and an increase in bicarbonate, specific conductivity, calcium, magnesium, potassium, total nitrogen, total phosphorus, color, turbidity, and chlorophyll *a*, coincided with major reduction in submersed macrophyte abundance. No statistically significant effects of macrophytes on water quality, however, could be demonstrated in Orange Lake, or Welaka ponds. With the exception of chlorophyll *a*, which was directly influenced by macrophyte abundance, water quality changes in Lake Pearl were caused primarily by hydrologic changes. This study demonstrates that overall lake water quality changes will occur only if macrophyte abundance is high and generally above levels acceptable to user groups. Alterations in water quality, resulting from aquatic plant management programs, will generally be short-term, and lakes will return to their limnological potential based on material loading rates, lake mean depth, sedimentation rates, and hydrologic flushing rates. Overall, lake hydrology and change in land use practices within the watershed can have greater long-term impacts on water quality than the invasion by macrophytes or their control.

In Orange Lake, Lake Pearl, and Welaka ponds, native emergent and floating leafed plants did not undergo any reduction in coverage or frequency of ocurrence as hydrilla expanded into these vegetation communities. Changes in water level seemed to affect those communities more than the abundance of hydrilla. Hydrilla, however, can eliminate native submersed vegetation. This apparently is caused by its greater ability to utilize free CO_2 at lower light intensities than native submersed vegetation. The growth form of hydrilla, which is characterized by dense continuous surface mats, can also limit light penetration, which also inhibits the growth of other submersed species. With increases in hydrilla, there is a trend toward reduced algal cell numbers. This trend is reversed when hydrilla abundance is reduced In Lake Pearl, following the major reduction of macrophytes, there was a shift in dominance from bluegreen to green algae. Similar phytoplankton changes were observed in Orange Lake as bluegreen algae became dominant with an increase in hydrilla. Whether these changes in algal community composition are directly related to hydrilla abundance or indirectly to changes in other factors, such as the abundance of specific plant nutrients, is unknown.

In Lake Pearl, a decline in total benthic macroinvertebrates and littoral zooplankton, with simultaneous increase in pelagic zooplankton, occurred as the hydrilla volume decreased. In Orange Lake, the greatest number and variety of invertebrates were collected from the vegetated regions, while the fewest were collected from the nonvegetated lake region. Among vegetative habitats, spatterdock supported the greatest number and variety of zooplankton species and the largest number of benthic macroinvertebrate taxa, whereas hydrilla supported a significantly greater number of benthic macroinvertebrates. Results for these lakes indicate that both the amount and type of aquatic vegetation influenced the abundance and species of invertebrates collected. Within the Welaka ponds, zooplankton and benthic macroinvertebrate populations were not significantly different among treatments or among vegetation levels.

In Orange Lake and Lake Pearl, large increases in total number and biomass of fishes occurred when hydrilla coverage exceeded 60%. These were due to increases in the population densities of small littoral fishes, such as bluefin killifish, golden topminnows, and bluespotted sunfish. At high hydrilla density, these fishes became a major biotic component. Sportfish populations underwent shifts in length frequency distributions, the distributions becoming skewed toward small to intermediate-sized individuals. Under these conditions, there was little or no growth and very few fish recruited into larger size classes, which caused an overall stunting of the sportfish populations. There also may have been a shift in predator dominance. For example, in Orange Lake, chain pickerel, a fish not sought after by most fishermen and a direct competitor of the preferred largemouth bass, increased greatly in abundance due to the establishment of their preferred habitat (vegetation). As hydrilla was removed from the system, these trends were reversed. The number and biomass of littoral species dependent on submerged vegetation for food and shelter were reduced but not eliminated.

Numbers of young-of-the-year and intermediate-sized sportfish declined when no longer protected from predation by dense vegetation cover. Concomitantly, there was a reduction in total sportfish biomass, but the average weight of individual sportfish increased. These changes in population occurred rapidly; however, 3 to 5 years are probably necessary for sportfish populations to stabilize after hydrilla is removed from the system.

Integrated plant management utilizing grass carp and herbicides was not successful for managing aquatic plants to prescribed densities in Lake Pearl. Herbicide treatments were required frequently, and control was not always precise. Introduction of grass carp did not control regrowth in treated areas; thus herbicide usage in the treatment area was not reduced. In the untreated area, grass carp reduced biomass of hydrilla only in small areas until stocking rates reached 16 fish/ha. This stocking rate, however, eliminated all hydrilla from the system, suggesting that without very intensive grass carp management, as in the relatively small Welaka ponds, it is unlikely that submersed vegetation can be managed for and maintained at a specific density. Floating leafed plants, however, increased in Lake Pearl, suggesting that large numbers of grass carp will not necessarily reduce or eliminate floating leafed vegetation. However, the long-term impact of grass carp on this type of vegetation is unknown.

The calculated monetary values for the Orange Lake fishery, as determined from creel survey data, indicate that a large economic loss can result from hydrilla infestation. Hydrilla infestation was low in 1979, and when creel survey data for that year are used as baseline to estimate fishery values, a 45% reduction in monetary value occurred in spring 1978, and a 38% reduction in spring 1982 when infestation was high. Although the fall fishery provides only 30% of the total revenue, it contributes almost a quarter of a million dollars to the local economy each year. Hydrilla, during its peak abundance in 1977, indirectly reduced the income derived from sportfishing by 90% in that year. Reduced revenues due to the presence of hydrilla in Orange Lake were not caused by decrease in angler success, but were the result of dramatic reductions in total angler usage. When hydrilla covered the entire lake, only individuals who lived close to Orange Lake fished, which resulted in the closure of several fish camps during 1977.

This study was not able to demonstrate definitively any direct impact of herbicides or grass carp on water quality or on invertebrate and fish populations. However, the data clearly demonstrate that biological and water quality changes occur as abundance of vegetation is altered by natural and anthropogenic factors. This suggests that the potential environmental impact of various aquatic plant management programs will be determined more by the amount of vegetation controlled than by the control method used, whether it be herbicides (used according to label instructions) or grass carp.

Recommendations

(1) The study data clearly indicate that grass carp can eradicate submersed vegetation from lake ecosystems at a fraction of the cost of herbicide methods. The long-term impact of complete removal of submersed vegetation on the aquatic environment is not known and should be determined.

At least 3 to 5 years of study are necessary to determine the ultimate impact of vegetation removal because many fish species are long-lived and water quality is significantly influenced by long-term lake hydrology. Consequently, research funds are needed for long-term research projects where aquatic vegetation has been eradicated by grass carp. If macrophytic vegetation is not necessary for the functioning of the ecosystem, grass carp could be used as a cost-effective biological control for aquatic weeds.

(2) Continua of lake types with regard to trophic conditions and biological communities exist in lakes in the United States. In the last decade, limnologists and fishery biologists have developed empirical models based on regression

analysis between important state variables to describe the various lake types. These models have become increasingly important to researchers and those charged with managing lakes because they allow quantitative predictions of change in important variables, given changes in other variables, and provide the basis for the development of further hypotheses concerning the functioning of lake ecosystems. Most empirical relationships, however, have concentrated on prediction of parameters associated with phytoplankton or fish communities, given measurements of nutrient supply or whole lake characteristics. It is difficult to predict the impact of aquatic plant management cn the limnology of lakes of different trophic status. Empirical models are needed to predict the impact of different densities of aquatic macrophytes on lake limnology and fisheries.

A survey of a large number of lakes, ranging from oligotrophic to eutrophic, should be conducted. Quantitative data pertaining to nutrient loading rates, lake nutrient concentrations, chlorophyll *a* concentrations, and zooplankton and fish biomass, as they relate to macrophyte abundance, should be collected and incorporated into empirical models that can be used to predict and manage weed growth. This type of information would permit a quantitative environmental assessment of the impact of different lake management strategies on lake ecosystems and allow the development of rational cost-benefit analysis.

(3) Studies in Russia, Poland, and Israel have demonstrated that ichthyofauna reconstruction and management have the potential to alleviate many of the problems associated with the eutrophication of water bodies. The United States currently relies on engineering techniques, such as nutrient diversion and nutrient limitation, which are extremely costly. Other than research to test the feasibility of manipulating zooplankton populations to control algae, and the use of grass carp to control weeds, there have been no major attempts in the U.S. to use fishery management techniques to counteract the eutrophication process. Research is needed to test concepts of ichthyofauna reconstruction and plant management developed by scientists in other parts of the world. Native and introduced fish species should be tested as weed control agents and management evaluations are made. If new methods prove successful, considerable monetary savings could be made as well as enhancement of both commercial and sportfisheries values.

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The complete report, entitled "Ecological Impact of Integrated Chemical and Biological Aquatic Weed Control," (Order No. PB 83-264 242; Cost: $26.50, subject to change) will be available only from:
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