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Overview of the Ecological Assessment Technology Area

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ABSTRACT

Research in the Ecological Assessment Technology Area of the Aquatic Plant Control Research Program has contributed extensively to understanding the basic and applied ecology of nonnative and native aquatic plants. Continuing ecological research in this technology area strives to be relevant to aquatic plant management through a focus on the following areas; 1) improving the effectiveness of management techniques, 2) evaluating the effectiveness of management techniques, 3) evaluating the impacts of management techniques on nontarget species and environmental quality, and 4) preventing new infestations of nonnative aquatic plants. While both current and future planned research falls within these areas, specific research needs for the future have been identified in the areas of 1) developing standard aquatic plant quantification methods, 2) developing protocols for identifying the potential of new species to create nuisance problems, and 3) developing spatial databases and spatial models of plant distribution.

Key words: aquatic plant ecology, efficacy, management, ecological impacts, aquatic macrophyte ecology.

INTRODUCTION

Nonnative aquatic plant species have been a multifaceted problem for water resources in the United States throughout this century (Gallagher and Haller 1990). All of the contiguous 48 states have unwelcome nonnative aquatic plant species that, in some measure, create water resource problems. The principal nonnative problem species in the United States are hydrilla (*Hydrilla verticillata* (L.f.) Royle), Eurasian watermilfoil (*Myriophyllum spicatum* L.), and waterhyacinth (*Eichhornia crassipes* (Mart.) Solms, Madsen 1997a). Many other species pose regionally-important problems, or are increasing in their range, including water lettuce (*Pistia stratiotes* L.), waterchestnut (*Trapa natans* L.) and Brazilian elodea (*Egeria densa* Planch.). As with terrestrial nonnative plant species, aquatic species constitute a major threat to the utility and integrity of natural ecosystems.

Water resource problems of most proximal interest for government agencies are the nuisances affecting navigation, flood control, hydroelectric power generation, mosquito-borne diseases and water supply. Other direct uses of water resources impeded by noxious plant growths include recreational use and shoreline property value.

In addition, other effects of these species on natural and manmade aquatic ecosystems have emerged in recent decades. The dense growths created by nonnative aquatic plants can degrade water quality, including decreased oxygen concentrations in water (Frodge et al. 1995), increased nutrient release from sediments (Seki et al. 1979, Frodge et al. 1991), and nutrient release from decomposing plant material (Smith and Adams 1986). Dense monospecific stands of nonnative species suppress the diversity and abundance of native plant species (Madsen et al. 1991), including rare, threatened and endangered plant species. Although aquatic plants are a superior substrate to bare bottom for macroinvertebrates, mixed stands of native plants are typically better as habitat than dense monospecific stands of nonnative species (Keast 1984, Hanson 1990). As the proportion of littoral zone taken up by dense monospecific stands of nonnative species increases, the predator/prey balance of lake ecosystems will shift, which may result in reduced size of predatory fish, including desirable game fish (Wiley et al. 1984, Lillie and Budd 1992). The shift from no plants or from native plants to dense stands of nonnative species will have substantial impacts on human use and ecological balances in aquatic ecosystems.

Recent research indicates that active management of nonnative species not only reduces the nuisance aspect to human activities, but can also restore native plant diversity and abundance, regardless of whether management approaches use herbicides (Getsinger et al. 1997), mechanical control (Eichler et al. 1993), or physical control (Eichler et al. 1995). Selective biocontrol approaches presumably will also preserve or enhance native species diversity and abundance.

IMPORTANCE OF ECOLOGICAL RESEARCH

Ecological research must be an integral component of ongoing aquatic plant control research in four areas: 1) improving the effectiveness of management techniques, 2) evaluating the effectiveness of management techniques, 3) evaluating the impacts of management techniques, and 4) preventing new infestations.

Ecological research can improve the effectiveness of management techniques through a better knowledge of both the target invasive species and nontarget species. For instance, studies of the seasonal growth cycle of nonnative species might reveal when they are most susceptible to control (Madsen 1997b). Increased knowledge of the nontarget species might improve timing of management techniques to minimize impacts on nontarget plants. A better understanding of the life cycle of target plant species might also explain failures in management programs and suggest system management approaches to reduce the reestablishment of nonnative species.

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Ecological studies are also needed to address aspects of aquatic plant management not traditionally included in cost/benefit analyses. In a time of shrinking economic resources to manage a growing problem, economic cost/benefit analyses have become critical elements for operational aquatic plant management programs. Although the economic cost of treating an acre of aquatic plants can be computed without considering ecological factors, this type of valuation gives no insight into how effective the technique is and how long the effects of the management technique will remain. Evaluations of management effectiveness should be considered as part of a cost/benefit analysis.

A growing concern of natural resource agencies is the impacts of aquatic plant management activities on the aquatic ecosystems they manage and regulate. Ecological studies of aquatic plant management activities will provide an objective and realistic look at the true impacts of management on aquatic resources. All management approaches have some impact on the ecosystem. Many have both positive and negative impacts that must be weighed in choosing an appropriate management technique. The lack of quantitative data on management impacts to aquatic communities hampers an objective evaluation.

Ecological research not only assists in developing plans to prevent the spread of a known nonnative nuisance species to new sites, but may also assist in predicting new species that may become a problem in the future.

HISTORY OF ECOLOGICAL ASSESSMENT AREA

The Ecological Assessment Area of the Aquatic Plant Control Research Program (APCRP) has been a national leader in studies of the basic ecology of aquatic plants. Studies focused on factors limiting aquatic plant distribution and abundance are among the most cited aquatic plant literature, including studies on limitation by sediment nutrients (Barko and Smart 1981b), aqueous nutrients (Barko 1982), salinity (Twilley and Barko 1990), water temperature (Barko et al. 1982) and light availability (Barko and Smart 1981a). In addition, previous research has included studies of water movement (James and Barko 1991), competition between native and nonnative aquatic plants (Smart et al. 1994), and phenological studies of aquatic plants (Luu and Getsinger 1990, Madsen 1997b).

Several simulation models have been developed to assist the aquatic plant manager in planning and implementing management strategies. These include models for stocking grass carp (AMUR STOCK, Stewart and Boyd 1994), herbicide dissipation (HERBICIDE, Stewart 1994), harvester operations (HARVEST, Sabol 1983), and insect biocontrol agents on waterhyacinth (INSECT, Stewart and Boyd 1992). A plant growth model was recently developed for the growth of hydrilla (HYDRIL, Best and Boyd 1996) and one is currently under development for Eurasian watermilfoil (MILFO). Ecological studies have been an important component of model development.

CURRENT RESEARCH AREAS

There are currently four research topics within the Ecological Assessment area:

1) Factors Influencing Propagule Production and Success in Submersed Macrophytes. Studies in this area are designed to assess the influences of environmental variables on the number, size, and probability of success of plant propagules, and the tuber or seed stage which may be the most vulnerable point in the life cycle of some plants. Research to date has evaluated the effects of temperature and growth stage (McFarland and Barko 1994) and sediment nutrient availability (McFarland and Barko 1996, Rogers et al. 1996) on propagules of selected submersed species. The establishment potential of regenerative fragments relative to their physiological status has also been investigated (McFarland and Barko 1996). Studies are currently being conducted to examine propagule emergence and growth relative to depth of burial in different sediments.

2) Factors Influencing Submersed Plants Invasions and Declines. This research area has investigated causes of nuisance plant population declines, predominantly Eurasian watermilfoil (Smith and Barko 1990, 1996). In recent years, it has sought to identify environmental factors related to successful invasions.

3) Coordination of Control Tactics with Phenological Events of Aquatic Plants. Carbohydrate storage patterns of waterhyacinth (Luu and Getsinger 1990), hydrilla and Eurasian watermilfoil (Madsen 1997b) were evaluated over several annual cycles to determine points at which these species might be most susceptible to control. Distinct low points in carbohydrate storage were identified for Eurasian watermilfoil and hydrilla that might be exploited for management.

4) Techniques for Establishing Native Aquatic Plants. In this research area, native plant establishment is studied as a mechanism to mitigate aquatic plant management operations, fill an empty niche in new reservoir systems without plants, and improve fish habitat in surface water resources (Smart et al. 1996).

FUTURE RESEARCH DIRECTIONS

The future research directions stem directly from the importance of ecological studies cited above.

Improving the effectiveness of management techniques will require research on all major aspects of plant allocation and propagation, phenology, seasonal studies, and whole-plant physiology. In addition, it may require whole-plant studies of why management techniques work, such as biocontrol and mechanical management techniques.

Evaluating the effectiveness of management techniques will require monitoring operational implementation of all management techniques, including biological controls, herbicides, mechanical and physical control approaches. To perform these studies, research needs to be done to develop standardized plant community quantification techniques. This will allow us to utilize data collected by cooperators or others across the country by ensuring that the data are directly comparable. As part of field evaluation studies, data may also be collected on desirable native plant communities to evaluate the impacts of management on nontarget species.

Evaluating the ecological effects of management techniques may combine both field studies of operational efforts, as well as controlled pond and mesocosm studies of biological, chemical, mechanical and physical techniques and their impacts on nontarget plants, animals, and water quality.

Efforts to minimize the spread of nonnative species and to mitigate for management operations will require some additional research on the restoration and creation of littoral zone habitats dominated by desirable native species.

Prevention of new introductions and the spread of existing problem species to new areas will require research on evaluation techniques for new potential nonnative invaders. The development of spatial databases and spatial models for aquatic plant distribution and management will further aid the development of management planning, to direct resources to the most potentially vulnerable areas.

Lastly, the needs of technology transfer will require further development of computer-based decision support tools, integrated between technology areas, to assist in the planning and implementation of operational aquatic plant management.

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LITERATURE CITED

Barko, J. W. 1982. Influence of potassium source (sediment vs. open water) and sediment composition on the growth and nutrition of a submersed aquatic macrophyte [*Hydrilla verticillata* (L.f.) Royle]. Aquat. Bot. 15: 91-103.

Barko, J. W., D. G. Hardin, and M. S. Matthews. 1982. Growth and morphology of submersed freshwater macrophyte in relation to light and temperature. Can. J. Bot. 60: 877-887.

Barko, J. W. and R. M. Smart. 1981a. Comparative influences of light and temperature on the growth and metabolism of selected submersed freshwater macrophytes. Ecol. Monogr. 51: 219-235.

Barko, J. W. and R. M. Smart. 1981b. Sediment-based nutrition of submersed macrophytes. Aquat. Bot. 10: 339-352.

Best, E. P. H. and W. A. Boyd. 1996. A simulation model for growth of the submersed aquatic macrophyte hydrilla (*Hydrilla verticillata* (L. F.) Royle). Technical Report A-96-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Eichler, L. W., R. T. Bombard, Jr., J. W. Sutherland, and C. W. Boylen. 1993. Suction harvesting of Eurasian watermilfoil and its effect on native plant communities. J. Aquat. Plant Manage. 31: 144-148.

Eichler, L. W., R. T. Bombard, Jr., J. W. Sutherland, and C. W. Boylen. 1995. Recolonization of the littoral zone by macrophytes following the removal of benthic barrier material. J. Aquat. Plant Manage. 33: 51-54.

Frodge, J. D., D. A. Marino, G. B. Pauley, and G. L. Thomas. 1995. Mortality of largemouth bass (*Micropterus salmoides*) and steelhead trout (*Oncorhynchus mykiss*) in densely vegetated littoral areas tested using in situ bioassay. Lake Reserv. Manage. 11: 343-358.

Frodge, J. D., G. L. Thomas, and G. B. Pauley. 1991. Sediment phosphorus loading beneath dense canopies of aquatic macrophytes. Lake Reserv. Manage. 7: 61-71.

Gallagher, J. E. and W. T. Haller. 1990. History and development of aquatic weed control in the United States. Rev. Weed Sci. 5: 115-192.

Getsinger, K. D., E. G. Turner, J. D. Madsen, and M. D. Netherland. 1997. Restoring native vegetation in a Eurasian water milfoil-dominated plant community using the herbicide triclopyr. Regul. Rivers: Res. Mgmt. 13: 357-375.

Hanson, J. M. 1990. Macroinvertebrate size-distributions of two contrasting freshwater macrophyte communities. Freshwater Biol. 24: 481-491.

James, W. F. and J. W. Barko 1991. Littoral-pelagic phosphorus dynamics during nighttime convective circulation. Limnol. Oceanogr. 36: 949-960.

Keast, A. 1984. The introduced aquatic macrophyte, *Myriophyllum spicatum*, as habitat for fish and their invertebrate prey. Can. J. Zool. 62: 1289-1303.

Lillie, R. A. and J. Budd. 1992. Habitat architecture of *Myriophyllum spicatum* L. as an index to habitat quality for fish and macroinvertebrates. J. Freshwater Ecol. 7: 113-125.

Luu, K. T. and K. D. Getsinger. 1990. Seasonal biomass and carbohydrate distribution in waterhyacinth. J. Aquat. Plant Manage. 28: 3-10.

Madsen, J. D. 1997a. Ch. 12. Method for Management of Nonindigenous Aquatic Plants. In: J. O. Luken and J. W. Thieret, eds. Assessment and Management of Plant Invasions. Springer, New York. pp. 145-171.

Madsen, J. D. 1997b. Seasonal biomass and carbohydrate allocation in a southern population of Eurasian watermilfoil. J. Aquat. Plant Manage. 35: 15-21.

Madsen, J. D., J. W. Sutherland, J. A. Bloomfield, L. W. Eichler, and C. W. Boylen. 1991. The decline of native vegetation under dense Eurasian watermilfoil canopies. J. Aquat. Plant Manage. 29: 94-99.

McFarland, D. G. and J. W. Barko. 1994. Influences of high temperature on growth and propagule formation in monoecious hydrilla. Proceedings, 28th Annual Meeting, Aquatic Plant Control Research Program, 15-18 November 1993, Baltimore, MD. Miscellaneous Paper A-94-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. pp. 108-115.

McFarland, D. G. and J. W. Barko. 1996. Investigations of the production, transport, and survival of monoecious hydrilla propagules in the tidal Potomac River. Technical Report A-96-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 41 pp.

Rogers, S. J., D. G. McFarland, and J. W. Barko. 1996. Evaluation of the growth of *Vallisneria americana* Michx. in relation to sediment nutrient availability. Lake Reserv. Manage. 11: 57-66.

Sabol, B. M. 1983. Simulated mechanical control of aquatic plants in Buffalo Lake, Wisconsin. Miscellaneous Paper A-83-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Seki, H., M. Takahashi, and S.-E. Ichimura. 1979. Impact of nutrient enrichment in a waterchestnut ecosystem at Takahama-Iri bay of Lake Kasumigaura, Japan. Water, Air, Soil Pollut. 12: 383-391.

Smart, R. M., J. W. Barko, and D. G. McFarland. 1994. Competition between *Hydrilla verticillata* and *Vallisneria americana* under different environmental conditions. Technical Report A-94-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Smart, R. M., R. D. Doyle, J. D. Madsen, and G. O. Dick. 1996. Establishing native submersed aquatic plant communities for fish habitat. Amer. Fish. Soc. Symp. 16: 347-356.

Smith, C. S. and M. S. Adams. 1986. Phosphorus transfer from sediments by *Myriophyllum spicatum*. Limnol. Oceanogr. 31: 1312-1321.

Smith, C. S. and J. W. Barko. 1990. Ecology of Eurasian watermilfoil. J. Aquat. Plant Manage. 28: 55-64.

Smith, C. S. and J. W. Barko. 1996. Evaluation of a *Myriophyllum spicatum* decline in reservoirs of the Tennessee and Cumberland Rivers. Technical Report A-96-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stewart, R. M. 1994. HERBICIDE simulation model for evaluating fate processes effects. In: Proceedings, 28th Annual Meeting, Aquatic Plant Control Research Program, 15-18 November 1993, Baltimore Maryland, Miscellaneous Paper A-94-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. pp. 69-76.

Stewart, R. M. and W. A. Boyd. 1992. User's Manual for INSECT (Version 1.0): A Simulation of Waterhyacinth Plant Growth and *Neochetina* Weevil Development and Interaction. Instruction Report A-92-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Stewart, R. M. and W. A. Boyd. 1994. Simulation model evaluation of sources of variability in grass carp stocking requirements. In: Proceedings of the Grass Carp Symposium, 7-9 March 1994, Gainesville, Florida. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. pp. 85-92.

Twilley, R. R. and J. W. Barko. 1990. The growth of submersed macrophytes under experimental salinity and light conditions. Estuaries 13: 311-321.

Wiley, M. J., R. W. Gorden, S. W. Waite, and T. Powless. 1984. The relationship between aquatic macrophytes and sport fish production in Illinois ponds: A simple model. J. Fish. Manage. 4: 111-119.