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Ecological perspectives in the management of submerged macrophytes

by
John W. Barko, Craig S. Smith, Doug Gunnison, and Andrew C. Miller

Scientists investigating sedimentation in *Hydrilla* beds in the Potomac River

Research within the ecological technology area of the Aquatic Plant Control Research Program (APCRP) has been directed toward determining the response of submersed aquatic macrophytes to a diverse array of environmental factors. Various factors, including light, water temperature, nutrition, and sediment composition, interact to determine the productivity, distribution, and species composition of submersed macrophyte communities.

During approximately the past five years, ecological research within the APCRP has been expanded to consider complex interactions among environmental factors and submersed macrophyte growth. Most recent studies have focused on mechanisms whereby submersed macrophyte communities influence their environment.

Based on the results of recent field and laboratory investigations conducted within the APCRP, submersed macrophytes apparently play a very active role in affecting environmental conditions, particularly within the sediment, in ways that potentially determine the duration and extent of nuisance conditions. This article summarizes these effects, discusses management implications, and describes related future research initiatives.

Sediment nutrient availability

Sediment provides the most important source of supply for nitrogen (N), phosphorus (P), and micronutrients to submersed macrophytes (see sidebar, next page). Thus, it is important to evaluate the effects of macrophyte growth on sediment nutrient availability. Evidence from field studies suggests that rooted submersed macrophytes, even with relatively diminutive root systems, are capable of markedly depleting pools of N and P in sediments. High productivity and biomass turnover of rapidly growing macrophyte species, for example, *Hydrilla verticillata* and *Myriophyllum spicatum*, can result in high rates of nutrient loss from sediments. Recent laboratory studies in the APCRP have demonstrated greater than 90 and 30 percent reductions in concentrations of exchangeable nitrogen and extractable phosphorus, respectively, from sediment by the growth of *Hydrilla verticillata*. Thus, even in fertile systems, aquatic macrophyte uptake may significantly reduce sediment nutrient availability. In general, it appears that N is depleted from sediments to a much greater extent than P (relative to macrophyte nutritional needs). Thus, N is generally more likely than P to limit macrophyte growth.

Pools of sediment nutrients available for plant uptake are regenerated by sedimentation, which provides new sediment material, by biological mixing of sediments, which transports nutrients in and out of the root zone, and by mineralization, which transforms nutrients into soluble forms that macrophytes can take up (Figure 1). By their effects on the environment, macrophytes influence the rate and extent of each of these processes. Some effects of macrophytes increase the rate of nutrient resupply, while others slow it down. Once sediment nutrient pools have been depleted, growth limitation will occur unless nutrient regeneration meets or exceeds plant requirements. Thus, nutrient regeneration processes are crucial to long-term maintenance of macrophyte productivity.

Primary Sediment Source
Nitrogen
Phosphorus
Iron
Manganese
Micronutrients
Primary Open Water Source
Calcium
Magnesium
Sodium
Potassium
Sulfate
Chloride

Sedimentation provides an important means of nutrient renewal to the littoral zone. Factors affecting sedimentation have been studied extensively in the open water of lakes and reservoirs, but to a much lesser extent in the littoral zone, particularly within the context of macrophyte nutrition. Aquatic macrophyte beds can serve as

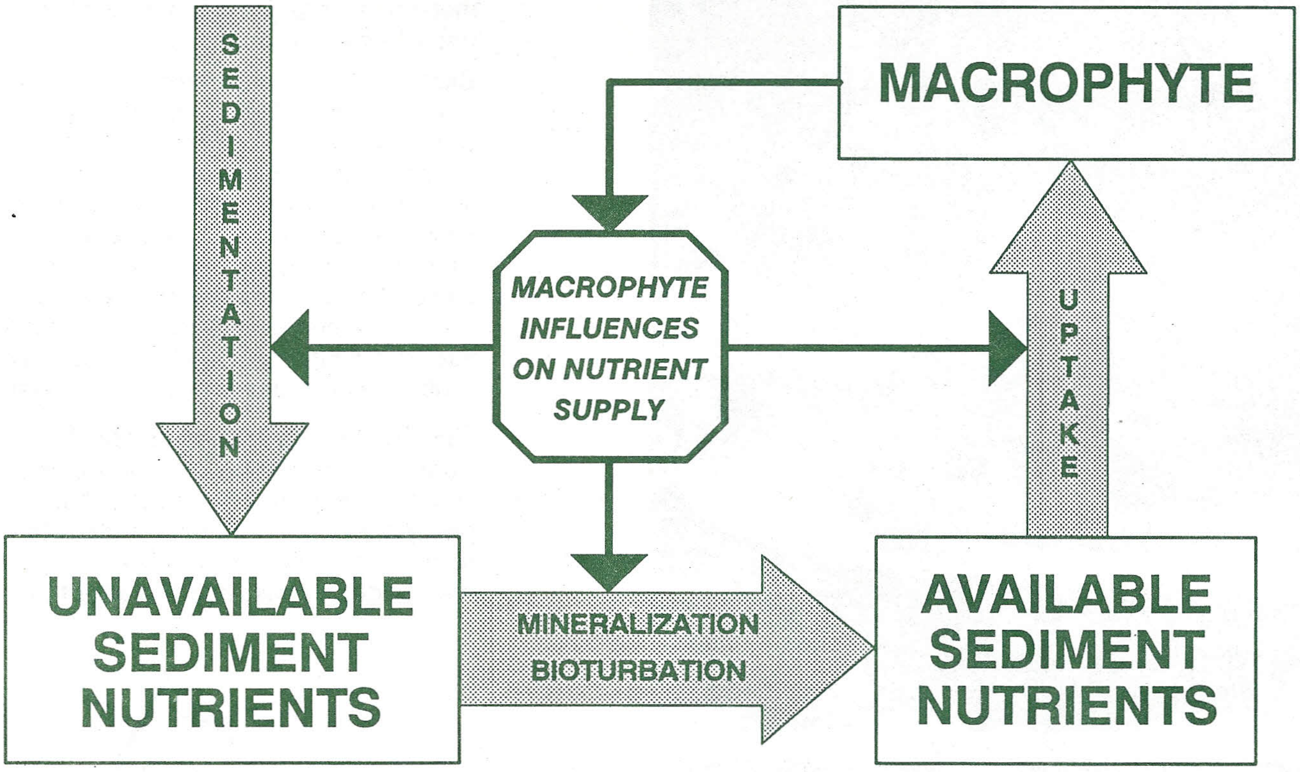


Figure 1. Conceptual model of processes influencing the supply of sediment nutrients to macrophytes

effective traps for inflowing dissolved and particulate materials. Sedimentation of algae from macrophyte leaf surfaces transfers nutrients absorbed from the water (by the algae) to the sediment surface. By reducing turbulence, aquatic macrophytes also serve an important role in sediment stabilization.

Based on field investigations conducted within the APCRP, sedimentation rates in macrophyte beds have been shown to vary considerably from rates determined in the adjacent open water. In Eau Galle Reservoir, Wisconsin, submersed macrophytes play an important role during the growing season in both promoting sedimentation and reducing sediment erosion. In macrophyte beds of the Potomac River, Washington, DC, however, sedimentation during the growing season is minimal due to restricted movement of water and sediment into dense stands of *Hydrilla*. Nevertheless, significant sediment deposition occurs during off-seasonal periods of high flow and turbulent mixing in the river, creating conditions ideal for the continued vigorous growth of submersed macrophytes.

In concert with the process of sedimentation, the activities of benthic invertebrates can significantly influence physical and chemical properties of sediment, affecting the availability of nutrients to aquatic macrophytes. For example, case construction and tube irrigation by chironomids and vertical mixing of sediment by tubificid worms can accelerate nutrient transport by increasing the area of the sediment-water interface, horizontal and vertical diffusional fluxes of nutrients within sediment, and sediment porosity (Figure 2). In addition, burrowing activities by tubificid worms promote microbial and chemical processes that release soluble nutrients from particulate phases. Dissolved nutrients may then diffuse to the sediment surface or be taken up by roots of macrophytes.

Sediment reworking by benthic invertebrates in the littoral zone may be important in intermixing newly accreted sediment into the root zone of aquatic macrophytes.

Through their role in decomposition and nutrient cycling, microorganisms as well as benthic invertebrates make available in sediments a variety of elements important to the nutrition of submersed aquatic macrophytes (Figure 2). Microbial transformations convert unavailable nutrients into forms that can be readily taken up by macrophytes and reduce the organic bulk of sediments, which increases nutrient availability. Many nutrient transformations, fueled by decompositional processes, are carried out by microorganisms that reach high population levels only in the root zone of aquatic macrophytes. The commonly increased abundance of bacteria in sediment supporting aquatic macrophytes may increase the rate of nutrient recycling in the root zone.

Chemical reduction of sediment resulting from the metabolic activity of microorganisms permits accumulation of N, P, and other nutrients to levels supporting the growth of submersed macrophytes. While ammonium-N can be produced under aerobic as well as anaerobic conditions, accumulation under aerobic conditions is usually restricted because of the ammonium-depleting activity of ammonium-oxidizing bacteria. Simi-

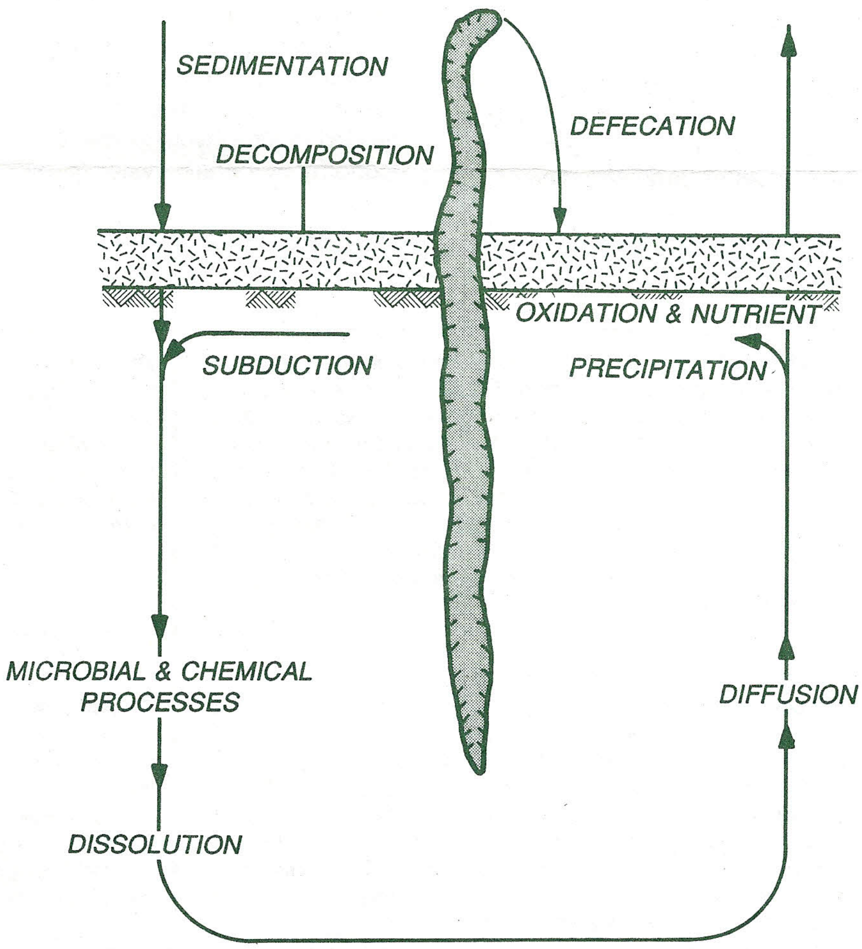


Figure 2. Linkages between benthic invertebrate activities and microbial processes affecting sediment nutrient availability

larly, accumulation of soluble reactive P in sediment is restricted under aerobic conditions because of precipitation with ferric oxyhydroxides. Thus, anaerobic conditions in sediment provided by microbial metabolism are important in ensuring sustained nutrient availability for submersed macrophytes.

Management implications and associated research initiatives

Over geological time, the filling of lake basins drives vegetative change in aquatic systems. However, shorter time scales are more relevant to many important management questions. Invasions of nuisance macrophytes, for example, often have cycles of a decade or so. Short-term compositional changes in aquatic macrophyte communities remain largely unexplained. Macrophyte-sediment interactions have the potential to exert strong influences at both population and community levels. Thus, a better understanding of these complex interactions should be useful in explaining short-term compositional changes, including species invasions and declines.

As described above, the sustained vigor of submersed macrophyte communities requires a balance between nutrient uptake and regeneration. Processes affecting this balance need to be considered explicitly within the context of macrophyte management. Inorganic sedimentation is frequently accelerated by human activities in the watershed, and for unknown reasons aquatic systems affected by these disturbances are often most susceptible to the invasion and subsequent explosive growth of introduced macrophyte species.

Nitrogen is a key element for the growth of rooted macrophytes. Thus, advances in our understanding of factors regulating sediment N availability are a prerequisite to the development of management approaches based on reductions in sediment nutrient availability. Toward this end, the role of submersed macrophytes in the N economy of aquatic systems will be investigated. A variety of physical, chemical, and biological processes (for example, sedimentation, mineralization, and particulate movement by benthic invertebrates) that potentially contribute to sediment N availability will be evaluated within the context of macrophyte nutrition.

Laboratory studies will be conducted to improve understanding of spatial aspects of sediment nutrient availability. Initially, these studies will examine the rooting depth of a variety of macrophyte species. This information will be used to assess the extent to which species with different rooting depths may respond to sediment nutrient reductions. The feasibility of lessening nitrogen availability to macrophytes by interfering with naturally occurring chemical and biological processes, thus retarding the growth potential of nuisance species, will be investigated. As an extension of this effort, the possibility of perpetuating reductions in nitrogen availability to nuisance species by interplanting preferred native macrophyte species will also be examined.

Dr. John W. Barko *is a research biologist and team leader in the Environmental Laboratory, US Army Engineer Waterways Experiment Station and the Scientific Technical Director of the US Fish and Wildlife Service Environmental Management Technical Center in Onalaska, Wisconsin. His aquatic plant studies currently focus on macrophyte influences on lake and reservoir ecology. Dr. Barko holds a Bachelor of Science degree in Biology and a Doctor of Philosophy degree in Plant Ecology/Limnology from Michigan State University.*

Dr. Craig S. Smith *is a research biologist in the Environmental Laboratory, US Army Engineer Waterways Experiment Station. His studies of aquatic plants concentrate on the ecology of their growth and management. Dr. Smith holds a Bachelor of Arts degree in Biology and Chemistry from Indiana University and a Doctor of Philosophy degree in Plant Ecology from the University of Wisconsin.*

Dr. Douglas Gunnison *is a research microbiologist in the Environmental Laboratory, US Army Engineer Waterways Experiment Station. His studies focus on the role of sediment and rhizosphere microflora in the nutritional ecology of aquatic plants. Dr. Gunnison holds a Bachelor of Arts degree in Biology and Chemistry from Kalamazoo College, a Master of Arts degree in Physiology from Western Michigan University, and a Doctor of Philosophy degree in Aquatic Microbial Ecology from Cornell University.*

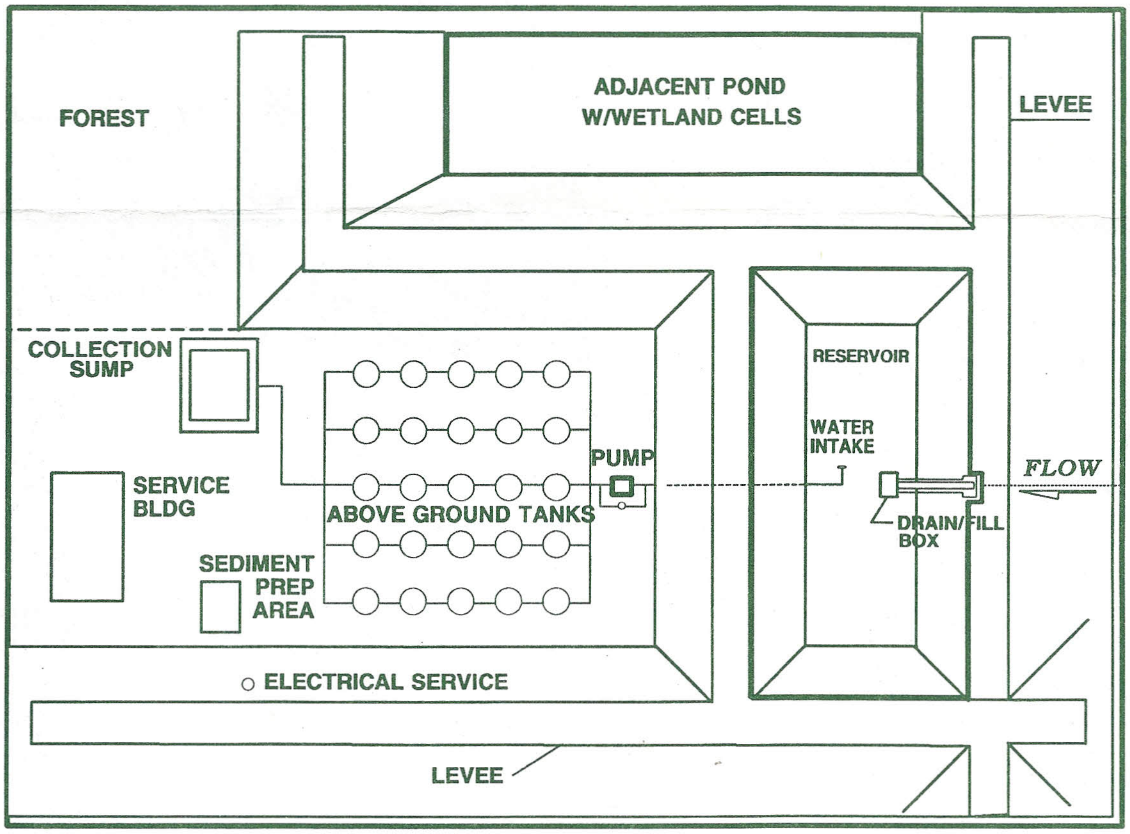
Dr. Andrew C. Miller *is a research limnologist in the Environmental Laboratory at the US Army Engineer Waterways Experiment Station. He conducts research on freshwater molluscs in large rivers and the habitat value of aquatic plants. Dr. Miller holds a Bachelor of Arts degree in Biology from Olivet College, a Masters degree in Biology from Central Michigan University, and a Ph.D. from the University of Louisville.*

Chemical Control Mesocosm System

The latest addition to the Lewisville Aquatic Ecosystem Research Facility (LAERF) in Lewisville, TX, is the Chemical Control Mesocosm System (CCMS). The initial CCMS is a large, aboveground configuration of twenty-five 2,800-gallon tanks (each 9 feet wide by 6 feet tall) that will be used to evaluate the efficacy of plant growth regulators (PGRs) and herbicides. This mesocosm system will allow researchers to bridge the gap between small-scale laboratory studies and large-scale field studies.

The system is designed to accommodate flow-through as well as static chemical exposure conditions. Target plants, such as hydrilla and Eurasian watermilfoil, will be grown in culture ponds located at the LAERF and placed in the CCMS before chemical treatment. Once selected herbicide or PGR doses and contact times have been achieved, treated plants will be returned to LAERF grow-out ponds for long-term efficacy evaluations. Chemically treated water will be drained from the tanks into a collection sump and later pumped into an adjacent, experimental wetland pond for final detoxification.

Future CCMS studies will focus on the selectivity of herbicides and PGRs on target and nontarget plant species. Other uses of the system may include aquatic plant competition studies and chemical toxicity assessment for nontarget organisms. Results from these and other CCMS studies will be used to provide guidance for improving the management of aquatic vegetation.



Chemical Control Mesocosm System

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Submersed macrophytes play a very active role in affecting environmental conditions, particularly within the sediment, in ways that potentially determine the duration and extent of nuisance conditions. The lead article in this issue discusses these effects, management implications, and related future research initiatives. The new Chemical Control Mesocosm System at the Lewisville Aquatic Ecosystem Research Facility is also announced.

AQUATIC PLANT CONTROL RESEARCH PROGRAM

This bulletin is published in accordance with AR 25-30 as one of the information dissemination functions of the Environmental Laboratory of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from the Corps of Engineers' nationwide Aquatic Plant Control Research Program (APCRP) can be rapidly and widely disseminated to Corps District and Division offices and other Federal and State agencies, universities, research institutes, corporations, and individuals. Contributions are solicited, but should be relevant to the management of aquatic plants, providing tools and techniques for the control of problem aquatic plant infestations in the Nation's waterways. These management methods must be effective, economical, and environmentally compatible. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such products. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Environmental Laboratory, ATTN: J.L. Decell, US Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call AC 601/634-3494.

ROBERT W. WHALIN, PhD, PE
Director

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

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