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Introduction: Workshop on Submersed Aquatic Plant Research Priorities

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INTRODUCTION

The quality and quantity of freshwater resources are stressed in the United States (Brown 1999) and worldwide (UNESCO 2003). Water use, "water crowding" (population supplied per unit accessible renewable supply), and use relative to accessible supply are increasing globally. Pollution from agriculture and industrial sources contribute substantially to water quality degradation in developed countries, and with globalization of trade these pollutants are becoming increasingly important in developing countries (Vörösmarty et al. 2005).

Degradation of water resources has reduced provisioning for human uses as well as "environmental flows" necessary to protect the structure and function of freshwater ecosystems and their dependent species (Vörösmarty et al. 2005). As a consequence of water quality degradation, 212 of Europe's 512 freshwater fishes are either extinct or threatened with extinction (Kottelat and Freyhof 2007). Riccardi and Rasmussen (1999) reported that 48.5% of North American freshwater mussels, 22.8% of freshwater gastropods, 32.7% of crayfishes, 25.9% of amphibians, and 21.3% of freshwater fishes are imperiled. They concluded that the projected mean future extinction rate for freshwater fauna is about the same as for species in tropical rainforests and approximately five times greater than the rate for terrestrial fauna. Similar impacts were documented in Canada (Dextrase and Mandrake 2006).

Human alteration of aquatic ecosystems, particularly hydrologic modification, facilitates invasion by nonindigenous species (Marchetti and Moyle 2001, Havel et al. 2005, Wei and Chow-Fraser 2006), which further stress aquatic systems. In the United States, nonindigenous species contributed to 68% of the fish extinctions in the past 100 years, and the decline of 70% of the fish species listed in the Endangered Species Act (Lassuy 1994). Invasive aquatic plant species can be particularly problematic because submersed aquatic plants account for a large proportion of the primary production in shallow lakes and ponds (Wetzel 2001), provide underwater structure that is critical for fish habitat (Petr 2000), regulate the rate of aquatic ecosystem succession (Carpenter 1981), play a significant role in lentic food webs and are a primary determinant of shallow lake trophic status (Scheffer 1998). They act as ecosystem engineers (Jones et al. 1994) that fundamentally alter aquatic ecosystems and facilitate establishment of new invaders that leads to invasion meltdown (Simberloff and von Holle 1999).

The cost of aquatic plant invasions is difficult to ascertain, however, because of the difficulty in assigning a price to ecosystem services, such as biodiversity (Wilson and Carpenter, 1999). Investment in management of invasive aquatic plants is often driven by anthropocentric impacts. Pimentel et al. (2005) cited a total cost of invasive aquatic plants in the United States of $110 billion/yr. Anderson (1993) cited a cost of aquatic weed control in irrigation districts in 17 western states alone of greater than $50 million/yr. Using rather simple methods with some crude assumptions Rockwell (2003) arrived at a total cost of aquatic weeds in the United States of $1 billion to $10 billion/yr. One submersed aquatic plant, *Egeria densa*, costs Oregon about $4 million/yr in lost boater recreation benefits alone (The Research Group 2000). By any measure the cost of the invasion is significant and the investment in management and research has not kept pace.

Improved management of all aquatic invasive species (AIS) requires research on the basic biology and ecology of pest species and control methods. Funding for research on invasive aquatic plants has been reduced in recent decades. For example, the US Army Corps of Engineers Aquatic Plant Control Program has been funded at less than 30% of its authorized level since 1995 (Kurt Getsinger, personal communication). Even if increased funding were authorized and appropriated, the invasive aquatic plant problem is growing rapidly, and available resources will likely continue to limit research efforts. Consequently, development of priorities for research that address key biological, ecological, and management questions are critical for effectively addressing invasive aquatic plant problems.

Research priorities for freshwater systems were developed over a decade ago (Naiman et al. 1995), however, the effort was broadly scoped. Priority research areas were identified as 1) ecological restoration and rehabilitation, 2) maintenance of biodiversity, 3) modified flow patterns, 4) ecosystem goods and services, 5) predictive management, and 6) solution of future problems. Funding agencies and nonprofit groups requested that the Western Regional Panel on Aquatic Nuisance Species (WRP) develop more focused priorities for AIS research to help direct available funding to appropriate problems. The diversity in habitats, organisms, pathways, and management options for AIS complicated WRP development of research priorities for AIS as a whole. While there are certainly broad questions that apply to all AIS, more narrowly focused research questions that address specific taxa or pathways may be developed more readily by smaller groups of experts and managers. Therefore, the WRP, in collaboration with the California Department of Food and Agriculture and

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the Center for Lakes and Reservoirs at Portland State University, hosted a workshop for submersed aquatic plant scientists and managers to develop research priorities for invasive, submersed aquatic plants.

WORKSHOP STRUCTURE AND PARTICIPATION

On 14-15 December 2005 a group of aquatic plant managers and scientists from throughout the country met for a workshop in La Jolla, California to develop research needs and priorities for submersed aquatic plants. The purpose of the workshop was not to dictate research policy; rather, it was intended to identify avenues, issues, and problems that require attention, including areas where aquatic plant management may be advanced by collaborations among disciplines. The experts were charged with developing a consensus on where their discipline currently stands and on the major, compelling research priorities for invasive aquatic plants.

Prior to the workshop, workgroups developed summary presentations on the current state of submersed aquatic plant science in nine disciplines:

- **Invasive Plant Ecology and Interaction Native Plant Communities**

  Evaluation of the ecological processes significant to the success and spread of invasive aquatic plants, their interaction with the physical environment, effects on native plant communities. (John D. Madsen, Chair)

- **Interaction of Invasive Plants with Environment and Other Biota**

  The effect of invasive plants on the littoral habitat for fish and other biota, environmental parameters (e.g., water quality), and ecosystem processes. (Eric Dibble, Chair)

- **Physiology**

  Advances in research on physiology and photosynthesis as it relates to invasive plant ecology and management. (Lars Anderson, Chair)

- **Invasive Plant Taxonomy**

  Advances in both classical and molecular taxonomy of invasive aquatic plants, issues in invasive plant identification, and future role in invasive plant management. (Michael Moody, Chair)

- **Biological Control**

  Advances in research on insect or pathogen biological control agents, both classical and naturalized, future prospects for biological control, and integration into ongoing management programs. (James Cuda, Chair)

- **Chemical Control**

  Advances in research on the use of herbicides to effectively control invasive aquatic plants, including new chemistry, new formulation, nontarget impacts, advances in detection, new uses, product stewardship, and other issues. Advances in understanding the impact of herbicide use on aquatic organisms other than vascular plants. (Kurt Getsinger, Chair)

- **Physical and Mechanical Management**

  Management of invasive plants through the use of mechanical devices (harvesters, cutters, rotovators, diver-operated suction harvesters) or through alteration of their physical environment (dredging, dyes, light alteration, nutrient alteration, drawdown, fire). (Charles Boylen, Chair)

- **Restoration and Revegetation**

  Advances in revegetation and restoration of native plants after management of invasive species, issues, and results. (Michael Smart, Chair)

- **Federal and State Management Issues**

  Session for state invasive plant management officials to discuss region-specific issues they see that could be resolved through additional research, and their view of how research has improved the ability to manage invasive aquatic plants. (Pat Akers, Chair)

Following the summary presentations to all workshop participants, workgroups met separately to develop recommendations for research priorities and directions and then reconvened in joint session for presentation and discussion of their recommendations. Summaries of the Restoration and Revegetation, Plant Ecology, Interactions with Other Biota, Physiology, Physical and Mechanical Management, and Federal and State Management workgroup conclusions are presented here. More detailed descriptions of the Biocontrol (Cuda et al. 2008), Chemical Control (Getsinger et al. 2008), and Taxonomy (Moody et al. 2008) workgroup results are reported in the following articles.

RESEARCH PRIORITIES

Restoration and Revegetation Workgroup

Factors that Influence Success of Restoration Efforts

Numerous biotic and abiotic factors influence the outcome of restoration efforts. Research is needed to identify the factors that are important determinants of success, the site specificity of the factors, and the importance of interaction between factors. Important considerations that were identified in the workshop include:

- Pathways of introduction and propagule pressure of invasive species,
- disturbance (wave action water level changes, management actions),
- water quality,
- sediment characteristics, and
- interactions among these factors.

Identification of Native Species Suitable for Restoration Sites

Much of research on the ecology of submersed aquatic plants has focused on a few problematic, invasive species; there has been relatively little work on native species. Multiple species plantings are beneficial to ecosystem function, resilience, and stability, but we lack information on how most native species respond to environmental conditions in restoration sites. Conditions in restoration sites are typically highly disturbed; a condition that favors invasive, weedy species. Identification of those native species that can tolerate disturbance is therefore critical to restoring native plant communities.

Role of Genetic Diversity

The importance of genetic diversity in restoration of terrestrial and wetland sites is recognized. While many submersed aquatics are clonal, and some invasive species exhibit remarkably low genetic diversity (Carter and Sytsma 2001), the importance of genetic diversity in native plant populations may be underestimated. Research on genetic diversity of undisturbed, native submersed aquatic plant communities is necessary to establish a baseline, or target, for restoration activities.

Biotic Interactions

Plant-plant interactions are important in structuring plant communities. Competition (through resource preemption and interference) and allelopathy have received some study in aquatic plant communities; mutualisms and facilitation have received little or no study. Research on herbivore impacts has focused on biocontrol agents targeted on invasive species, but little work has been done on the role of herbivory in structuring native plant communities. Better understanding of intraspecific and interspecific plant interactions and the importance of herbivory would aid in establishment and maintenance of restoration sites.

Natural Dispersal and Founder Colony Establishment

Dispersal of invasive species propagules and propagule pressure determine invasion rates and persistence of restored native plant communities. The ability of newly established, native plant communities to resist invasion and expand coverage is likely a function of planting density, species diversity, and propagule type, *inter alia*. Research is needed to determine the optimal size of restoration sites, type of propagule (containerized plants, bare root, vegetative propagules, seeds), species mix, and planting density necessary to establish resilient and stable native aquatic plant communities.

Seed Banks

Seeds are considered a relatively unimportant mode of establishment for many aquatic plants, however, the importance of submersed aquatic plant seed banks is relatively understudied. Research is needed on seed and vegetative propagule banks to determine whether reestablishment from native plant seed and propagule banks is feasible.

Propagule Availability

Large-scale restoration requires large numbers of native plant propagules. Currently access to propagules is limited. Research is needed to develop economically viable, mass production techniques for aquatic plant restoration activities.

Ecology Workgroup

Plant Demographic/Life History Analysis

Growth rate, reproductive success, phenology, and dispersal are fundamental characteristics that determine the success of a species and an individual in a given environment. Understanding interspecific differences in these characteristics is necessary for better understanding of native community dynamics and invasive species management. More complete life history and physiological ecology studies of invasive and representative native species is required for management of aquatic plants and systems.

Community Dynamics

The effect of environmental gradients on species composition and changes over time are basic plant community characteristics. Zonation in aquatic plant communities over a depth gradient is a commonly observed phenomenon. Successional changes in submersed aquatic plant communities are less commonly described. Research on aquatic plant ecology offers an opportunity to test the robustness of plant community theory derived from terrestrial plant communities and has direct management implications. Long term studies of vegetation dynamics in relatively stable to highly disturbed systems are required.

Spatially-relevant Models of Invasion

Information on community dynamics, life history, and ecophysiology may be used to formulate predictive models of submersed aquatic plant communities that can be used for management. Predictive models of invasion probability may be constructed by integrating models across multiple time scales (the relevant ecophysiology time scale may be less than one minute but relevant successional time scales may be decades to centuries) with models of natural dispersal and pathways of human-mediated spread. Modeling of aquatic plant communities and invasions lags behind that for terrestrial plants and aquatic animals. More effort should be applied to developing models of aquatic plant invasions or in adapting terrestrial plant or aquatic animal models to aquatic plant communities.

Interactions with Other Biota Workgroup

Plants as Habitat

Submersed aquatic plants are habitat and a food resource for a variety of organisms. While the role of plants in providing fish and invertebrate habitat is clear, the relationship between plant architecture, abundance, diversity, biomass, and growth is not well defined. Research is needed on the impact on habitat quality of natural successional and spatial changes in the plant community as well those that occur when non-native species invade or are removed from the community in control programs.

Fisheries Management

Much of the research on the role of plants in fisheries management has focused on artificial systems (e.g., Southern reservoirs) and a few sport fishes. More work is needed on the fish/aquatic plant interaction in natural systems and on other phytophilic fishes, especially rare and threatened species already impacted by habitat alteration and shoreline development (salmonids, killifish, darters, and rare minnows).

Trophic and Littoral/Pelagic Linkages

Work on plant/invertebrate relationships has been conducted, indeed the role of macrophytes as a refuge from predation for zooplankton is a fundamental feature of current theory relating to multiple stabile states in shallow lakes; however, more research is needed on the trophic relationship among macrophytes, plankton, periphyton, macroinvertebrates, and early life stages and adult fishes. For example, more research is needed on how changes in the vegetation in the littoral zone alters detritus-based food webs and linkages with the pelagic zone, and the host specificity of macrophyte parasites and pathogens.

Habitat Manipulation, Physical, and Mechanical Control Workgroup

Physical Control

Physical management of aquatic plants is considered to have relatively benign environmental impacts, although there is evidence of positive and negative impacts on fish populations and nontarget plants. Additional research is needed to quantify the impacts of physical control methods on the aquatic ecosystem. Furthermore, while commonly cited, there is little evidence that repeated control efforts, or timing of control efforts to “weak points” in the target plant’s lifecycle, results in more effective control of weeds. Information on the phenology and ecophysiology of native and invasive plants is necessary to develop the utility of this approach.

Epilimnetic Mixing

Nitrogen availability in the sediments is thought to commonly limit production of submersed aquatic plants when light resources are adequate. The nitrogen cycle in sediments is a function of redox potential and microorganism metabolism. When anoxic sediments are oxygenated denitrification can occur, which results in nitrogen loss from the sediments. Recently, epilimnetic mixing has been proposed as a technique to oxygenate surface sediments and thereby reduce nitrogen availability in sediments and plant production. The feasibility of this approach to limiting submersed aquatic plant growth and perhaps select for native plants that may have a lower nitrogen requirement requires study. Evaluation of the effect of eplimnetic mixing on nitrogen availability in the sediments and the subsequent impact on plant community composition is needed.

Harvesting/Shredding

While aquatic plant harvesting has been conducted for decades, there are few long-term studies of repeated harvesting on plant communities, fish populations, and invertebrates. Research is needed on methods to reduce “take” of fish and on using harvesters to maximize habitat value.

Propagule Longevity and Viability

Plant response to physical control methods is determined by an interaction between physiology and phenology and the environment. The response of seeds and vegetative propagules to physical manipulation of the environment is poorly understood. With better understanding of species-specific responses, this aspect of plant biology may possibly be exploited to enhance native plants and to inhibit invasive species.

Habitat Alteration

Plants exhibit differential responses to environmental changes. Better understanding the ecology of submersed aquatic plants would be beneficial in predicting the impact of various habitat alterations, e.g., organic matter addition to sediments, manipulation of the light climate, reduction in nutrient loading, and drawdown. For example, organic matter addition to sediments has proven effective in reducing plant biomass in greenhouse and dewatered canal systems. This technique requires further research to identify the type of organic matter that is most effective, mode of action, how much needs to be added to sediments for effectiveness, how long effect lasts, and differences in species response. If effective, the technique requires development of application methods to permit use in systems that cannot be drawndown.

Physiology Workgroup

Photosynthesis

Submersed aquatic plants exhibit photosynthetic adaptations to the aquatic environment that are viewed as adaptations to low light and inorganic carbon availability. Some species, particularly some invasive species, use C4-like photosynthetic biochemistry under some conditions to concentrate CO_2 at the chloroplast and minimize photorespiration; some can use bicarbonate ion as an inorganic carbon source. The benefits of these adaptations are recognized, however, the associated costs are poorly understood. For example, nitrogen is viewed as an important limiting nutrient for aquatic plant growth, but the impact of these biochemical adaptations on nitrogen-use-efficiency has received little or no study.

Water Relations

Submersed plants have reduced xylem and vestigial stomata, features that obviously relate to their habitat. Still, maintenance of osmotic balance and translocation of solutes are fundamentally important to all plant life. Research is needed on the role of aquaporins in water and solute transport, salinity tolerance, and mechanisms of translocation. This research could lead to new chemical control methods that focus on disrupting these processes.

Root Function

Historically, roots in submersed aquatic plants were considered to function primarily as holdfasts but more recent research has demonstrated their importance in nutrient uptake. More research is needed on the role of aquatic plant roots in competition, plant growth regulation through hormone production, nutrient acquisition, and mycorrhizal associations.

Molecular Biology

Increasingly, plant science is focusing on the molecular basis of plant development, physiology, and management. Submersed aquatic plants are excellent models for studying the genomic basis of species identification, invasiveness, and management, Research is needed to determine the genome of important weedy species (*Hydrilla verticillata*, *Egeria densa*, *Myriophyllum spicatum*, *Potomogeton crispus*) and on comparison of invasive and native plant gene functionalities.

Chemical Ecology

Interactions between submersed macrophytes, periphyton, and associated fauna are understudied. The role of chemical defenses produced in response to herbivory and pathogens (phytoalexins) in submersed aquatic plants is unknown. Allelopathic interactions have received some study but important questions relating to methodology and compound identification limit advancement of the research.

Plant Growth Regulation

The role of hormones in plant growth and development is well known. Plant growth regulators (PGRs) may also provide important new management tools for reducing growth rate, manipulating canopy architecture, reducing propagule production, and stimulating propagule germination in weedy species. Research is needed on gene expression of PGRs, translocation, and receptor function.

Management Workgroup

Herbicide Resistance

Recent evidence of resistance of *Hydrilla verticillata* to fluridone has seriously impacted management in Florida—a higher application rate (and cost) is required for control. Similar resistance problems have developed in terrestrial weed management. Research is needed on strategies to avoid and overcome herbicide resistance problems in aquatic systems (i.e., do terrestrial strategies work in aquatic systems?).

Microorganism Interactions

Induction of microorganisms that preferentially degrade an aquatic herbicide has reduced herbicide efficacy in some circumstances. Research is needed on suppression or mitigation of these effects.

New Herbicide Registration

For many years the number of herbicides available for aquatic use was limited. Problems with resistance and induction of herbicide-degrading microorganisms illustrate the need for new tools for chemical control. Research is needed on efficacy and nontarget impacts of new herbicides, which should include strategies for use that mitigate resistance and environmental impacts.

Weed Control in Flowing Water

Methods for weed control in flowing systems are limited. New techniques, including sediment amendment, herbicide application to sediments during drawdown and through metering systems, and alteration of canal morphology should be developed.

Grass Carp

Grass carp (*Ctenopharyngodon idella),* herbivorous fish native to the Amur River in Asia, are commonly used for nonselective weed control. Fish that are triploid are required in some states to reduce the possibility of reproduction following release. Despite their widespread and long use, there are many unanswered questions about grass carp. Research is needed to quantify the probability of sterility of triploid fish, the possibility of reversion to a fertile form, and the longevity of triploid versus diploid fish. Temperature-based life tables are required to anticipate mortality of diploid and triploid fish. Research to develop genetically modified fish with limited lifespan or to terminate fish following a specified period of deployment is necessary. Better methods are needed to census fish and to minimize predation. Research is also needed on selectivity in feeding and tolerance to brackish water.

Biological Control

As with all biological control efforts, better means of predicting efficacy of new agents and more surveys for agents in regions where invasive species originated are required. Can lessons learned in terrestrial biocontrol research be readily transferred to aquatic systems? Research is also needed on integrating chemical and other techniques with biocontrol efforts.

Impacts

Better management of aquatic ecosystems requires understanding of direct and indirect impacts of invasive plants on native plant communities, water quality, fish, recreation, etc. Documentation of economic impacts and management costs are required to develop management models that explicitly account for the cost of not managing aquatic weeds and to optimize expenditure of management funds.

Mechanical Control

In situations where chemical and biological control tools are unavailable, mechanical harvesting is a commonly used option. Mechanical harvesters do have nontarget and other environmental impacts that require study and mitigation. For example, harvesters collect small fish as well as plants. The impact of harvesting on juvenile fish population can be significant, and methods should be developed to minimize fish take during harvesting operations. Harvesters create fragments that can be dispersed by water currents; additional work needed on fragment viability and methods to minimize fragment establishment.

Plant Biology

Effective management requires a good understanding of aquatic plant biology and the response to management actions. Vegetative propagules allow many submersed aquatic plant to perennate. Methods to document the abundance, depth distribution, and viability of propagules are required.

Seasonal changes in growth rates, sprouting of propagules, and germination of seeds for important native species and invasive species are needed to optimize timing of management actions.

Education and Outreach

An informed public facilitates early detection of new invasive species and management of aquatic systems. Better understanding of the response of various audiences to invasive species and management messaging is required. Information on the messages that resonate with target audiences and motivate action is required.

Algae

Shallow, mesotrophic lakes exhibit multiple stable states and can exist as algae-dominated, turbid water systems or macrophyte-dominated, clear water systems. Aquatic plant management can result in a shift in stable state to an algae-dominated system. More research is required on management of algae and identification of those water bodies that are subject to a switch in stable state following management.

Technology Transfer

Transfer of new management information from researchers to managers is necessary. Limited travel opportunity for many managers necessitates development of local opportunities for technology transfer. Development of state or regional aquatic plant management technology centers is required to facilitate technology transfer.

CONCLUSIONS

There was clear overlap of research priorities among workgroups. For example, work on vegetative propagules was cited as a research priority in multiple workgroups and work in plant physiology is critical to advances in chemical control. Potential synergies between disciplines suggest that advancement of research in aquatic plant biology and management may be most effectively pursued through interdisciplinary teams of scientists and managers working together using an adaptive, ecosystem-based management approach.

Managers identified the need for research in several areas that were also identified by the science workgroups, but also cited the need for work on quantifying impacts and public outreach and education. While much of the research currently conducted on submersed aquatic plants is management driven, increased technology transfer and enhanced communication between scientists and managers may facilitate problem-solving research. Technology transfer currently occurs at meetings of organizations with an applied aquatic plant management focus, such as the Aquatic Plant Management Society and its chapters and the North American Lake Management Society and its affiliates. Establishment of regional or state Aquatic Plant Management Centers would enhance local technology transfer capabilities.

Despite the clear ecological and economic impacts of invasive aquatic plants, lack of adequate funding for research support was the most significant obstacle to advancement of aquatic plant management. Inadequate funding limits the attractiveness of the aquatic plant management field for students, postdoctoral researchers, and junior faculty. Dedicated funding for university-based research on aquatic plant biology and management is necessary for addressing the research and outreach needs identified in the workshop. Given regional and state-specific aquatic plant problems, the magnitude of the economic impact, and the critical importance of protecting increasingly valuable freshwater systems full funding of authorized federal agencies and dedicated funding of $10 million/year for 10 regional and state centers and $5 million/year for a competitive research grant program is required.

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LITERATURE CITED

Anderson, L. W. J. 1993. Aquatic weed problems and management in North America (a) Aquatic weed problems and management in the western United States and Canada. pp. 371-391. *In:* A. H. Pieterse and K. J. Murphy (eds.). Aquatic Weeds. Oxford University Press, Oxford.

Brown, T. 1999. Past and future freshwater use in the United States: a technical document supporting the 2000 USDA Forest Service RPA Assessment. Gen. Technical Report. RMRS-GTR-39. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 pp.

Carpenter, S. R. 1981. Submersed vegetation: an internal factor in lake ecosystem succession. Am. Midl. Nat. 118: 372-383.

Carter, M. C. A. and M. D. Sytsma. 2002. Comparison of the genetic structure of North and South American populations of a clonal aquatic plant. Biol. Invasions 3: 113-118.

Cuda, J. P., R. Charudattan, M. J. Grodowitz, R. M. Newman, J. F. Shearer, M. L. Tamayo, and B. Villegas. 2008. Recent advances in biological control of submersed aquatic weeds. J. Aquat. Plant Manage. 46: 15-32.

Dextrase, A. J. and N. E. Mandrake. 2006. Impacts of alien invasive species on freshwater fauna at risk in Canada. Biol. Invasions 8: 13-24.

Getsinger, K. D., M. D, Netherland, and T. J. Koschnik. 2008. Improvements in the use of aquatic herbicides and establishment of future research directions. J. Aquat. Plant Manage. 46: 32-41.

Havel, J. E., C. E. Lee, and M. J. Vander Zanden. 2005. Do reservoirs facilitate invasions into landscapes? Bioscience 55: 518-525.

Jones, C. J., J. H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. Oikos 69: 373-386.

Kottelat, M. and J. Freyhof. 2007. Handbook of European Freshwater Fishes. Kottelat, Cornol and Freyhof, Berlin. 646 pp.

Lassuy, D. 1994. Aquatic nuisance report overview. Fisheries 19: 14-17

Marchetti, M. P. and P. B. Moyle. 2001. Effects of flow regime on fish assemblages in a regulated California stream. Ecol. Appl. 11: 530-539.

Moody, M. L., D. H. Les, and J. M. DiTomaso. 2008. The role of plant systematics in invasive aquatic plant management. J. Aquat. Plant Manage. 46: 7-15.

Naiman, R. J., J. L. Magnuson, D. M. McNight, J. A. Stanford. 1995. The Freshwater Imperative, a Research Agenda. Island Press, Washington D.C. 165 pp.

Petr, T. 2000. Interactions between fish and aquatic macrophytes in inland waters. A review. FAO Fisheries Technical Paper. No. 396. Rome, FAO. 185 pp.

Pimentel, D. R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecol. Econ. 52: 273-288.

Riccardi, A. and J. B. Rasmussen. 1999. Extinction rates of North American freshwater fauna. Conserv. Biol. 13: 1220-1222.

Rockwell, H. W. 2003. Summary of a survey of the literature on the economic impact of aquatic weeds. Aquatic Ecosytem Restoration Foundation. 18 pp.

Scheffer, M. 1998. The Ecology of Shallow Lakes. Chapman and Hall (Population and Community Biology Series 22). 357 pp.

Simberloff, D. and B. von Holle. 1999. Positive interactions of nonindigenous species: invasional meltdown. Biol. Invasions 1: 21-32.

The Research Group. 2000. Economic Analysis of Containment Programs, Damages, and Production Losses from Noxious Weeds in Oregon. Noxious Weed Program, Oregon Department of Agriculture. 40 pp.

UNESCO. 2003. Water for People, Water for Life. United Nations World Water Development Report. UNESCO Publishing, New York. 575 pp.

Vörösmarty, C. J., C.Lévêque, R. Revenga, C. Bos, Caudill, J. Chilton, E. M. Douglas, M. Meybeck, D. Prager, P. Balvanera, S. Barker, M. Maas, C. Nilsson, T. Oki, C. A. Reidy. 2005. Freshwater, pp. 165-207. *In:* R. Hassan, R. Scholes, and N. Ash (eds.). Ecosystems and Human Well-being: Current State and Trends: Volume 1 (Millenium Ecosystem Assessment Series). Island Press, Washington D.C.

Wei, A. and P. Chow-Fraser. 2006. Synergistic impact of water level fluctuation and invasion of Glyceria on Typha in a freshwater march of Lake Ontario. Aquat. Bot. 84: 63-9.

Wetzel, R. G. 2001. Limnology: Lake and River Ecosystems. 3rd Edition. Academic Press, New York. 1006 pp

Wilson, M. A. and S. R. Carpenter. 1999. Economic valuation of freshwater ecosystem services in the United States: 1971-1997. Ecol. Appl. 9: 772-783.