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WORKSHOP SUMMARIES

Evaluation of Invasions and Declines of Submersed Aquatic Macrophytes[1]

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ABSTRACT

During the past 60 yr, sightings of aquatic macrophyte species in geographic regions where they had previously not been found have occurred with increasing frequency, apparently due to both greater dispersal of the plants as a result of human activities as well as better documentation of plant distribution. Intercontinental invasions, such as *Myriophyllum spicatum* and *Hydrilla* into North America, *Elodea canadensis* into Europe and *Elodea nuttallii, Egeria densa* and *Cabomba caroliniana* into Japan, have generally been well documented. However, the spread of an exotic species across a continent after its initial introduction (*e.g.*, *Potamogeton crispus* in North America) or the expansion of a species native to a continent into hitherto unexploited territory (*e.g.* ,the expansion of the North American native *Myriophyllum heterophyllum* into New England) have received little attention. Natural declines in aquatic macrophyte communities have also received little scientific study although there are many accounts of macrophyte declines. The best-documented example comes from the marine literature where extensive declines of eelgrass (*Zostera*) occurred in the 1930s along the Atlantic coast due to a pathogenic marine slime mold ("wasting disease").

The aim of this workshop was to identify examples of invasions or natural declines of aquatic macrophyte species throughout the world and assess the importance of environmental factors in their control. Forty-five scientists and aquatic plant managers from ten countries participated in the workshop. Eleven of the participants contributed written evaluations of species invasions and declines in their geographic region. These were distributed to registered participants prior to the meeting and served as the starting-point of workshop discussions. To address the topics raised in the working papers, the participants divided into four working groups to evaluate:

1. Environmental controls of species invasions.
2. Biotic controls of species declines.
3. Abiotic controls of species declines.
4. Impact of management practices on macrophyte invasions or declines.

Each working group was asked to identify existing evidence, the need for additional evidence and management implications of their topics and then requested to discuss their findings with the entire workshop at the conclusion of discussions.

1. ENVIRONMENTAL CONTROLS OF SPECIES INVASIONS

While chance was acknowledged as a, if not "the," major factor determining species invasions, the environmental factors determining an invader's success were recognized to vary with scale such that different factors were more important on a continental or macroscale (*e.g.* Europe to North America) than on a regional or microscale (*e.g.* within a particular lake or river reach). On a macroscale, the potential for a species to invade hitherto unexploited territory depends upon opportunity, dispersal agents, and mode of dispersal/reproduction. Once introduced to a new area, its ability to establish and expand appears largely to depend upon climate (temperature and photoperiod). For example, Kunii noted that the northerly limit in Japan for the exotic *Egeria densa* is set by temperature while Chambers observed that the present-day distribution of *M. spicatum* in North America is generally limited to regions with mean annual dewpoint temperatures greater than 35C, suggesting that desiccation survival may limit aquatic plant dispersal in arid regions.

Once an exotic species is already present in a region, its introduction into any particular lake or river reach will be primarily determined by the level of human activity or, to a lesser extent, watershed barriers to dispersal (*e.g.* downstream

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flow). For example, Madsen noted that most exotics are introduced at sites of public access, particularly boat launches. Once introduced to a specific water body, an invader's ability to establish and expand will be determined by a variety of environmental factors including water and/or sediment chemistry, irradiance, stable water levels (particularly for plants in reservoirs) and water movement (flow or wave action). Disturbance or, conversely, community stability was also recognized as a factor that may contribute to species invasions in that disturbance creates a gap, thereby opening a community to invasion. Disturbance phenomena range in scale from geographic regions (*e.g.* hurricane activity) to entire watersheds or lakes (*e.g.* human development) to within communities (*e.g.* fish nests, turtle trails). Disturbance is not always a precursor to invasion but it may lead to opportunistic exploitation. For example, Nichols noted that in the Upper Great Lakes region, *P. crispus* and *M. spicatum* tended to invade lakes with histories of disturbance as a result of human activity.

To better identify environmental factors influencing species invasions, further research on species autecology and long-term monitoring to detect and track invasions were recommended. However, it is unlikely that intercontinental invasions will ever be predictable since they depend upon dispersal agents. Once an exotic species has become established in a region, it is almost a 100% certainty that it will invade other water bodies in that region. The development of models relating species survival and growth rates to environmental factors may assist in predicting the potential distribution of an exotic species throughout a region.

2. BIOTIC CONTROLS OF SPECIES DECLINES

Presently, there is limited quantitative evidence of biotic controls in species declines due to a lack of "before and after" data. Interspecific competition has often been cited as an important factor in the replacement of native species by exotics. For example, Nichols observed that *P. crispus* and *M. spicatum* had replaced native species in the Upper Great Lakes region, while Bates indicated that *Hydrilla* had displaced *Zostera* and *Najas* in the Mobile River delta, *C. demersum*, *Cabomba sp.*, *M. spicatum* and *Potamogeton illinoensis* in Lake Seminole, and a variety of native species in Alabama and Georgia. Quantitative data to verify the role of interspecific competition in species declines are limited. However, Madsen reported that the expansion of *M. spicatum* throughout Lake George, New York, coincided with a significant decrease in species richness. The mechanism by which exotics appear to out-compete native species has yet to be elucidated. In addition, further research is required to determine if there are predictable replacement sequences (species A to species B to species C), environmental conditions controlling replacement sequences (*e.g.* disturbance, carrying capacity of the environment) and, in the case of native species, whether these changes in community dominance represent replacements or succession. There is no evidence to indicate the interspecific competition plays a role in natural declines of nuisance exotic species.

In addition to competition, herbivores and plant pathogens may also mediate species declines although little is known concerning these processes. Sheldon noted the decline in *M. heterophyllum* in a New Hampshire lake and *M. spicatum* in a Connecticut and several Vermont lakes was associated with the presence of high densities of aquatic herbivores (weevils and/or aquatic Lepidopteran). Likewise, the reduction in *M. spicatum* populations in some Ontario lakes has been attributed to weevil populations. The importance of plant pathogens in controlling macrophyte declines is even less well documented. The decline of *M. spicatum* in lakes near Madison, WI, has been attributed to Northeast disease, a possible viral pathogen. Shearer reported that research is presently underway to develop a fungal isolate as a biological control agent for commercial use. However, the management of nuisance aquatic macrophytes by herbivore or pathogenic biological control agents will likely be limited by quarantine regulations which restrict the introduction of non-native herbivores or pathogens and by the need for extensive testing to evaluate the action of herbivores or pathogens under conditions which mimic the natural situation with respect to the chemical and physical environment, and the vigor of the host population.

3. ABIOTIC CONTROLS OF SPECIES DECLINES

Few natural declines of aquatic macrophyte species have been studied quantitatively although personal accounts suggest that natural species declines may be common. In studying declines, it is important to identify the time interval (long term (*i.e.* >3 years) versus short term (≤ 1 year) declines) and the specificity (*i.e.*, one species versus all species). A variety of abiotic factors controlling declines have been identified including insufficient light caused by biogenic turbidity or suspended sediments, water movement (flow or wave action), temperature, substrate composition, and nutrient availability. Observations that changes in abiotic factors have brought about natural declines in aquatic macrophyte communities have led to management attempts aimed at manipulating one or more of these factors to reduce aquatic macrophyte growth. Chambers noted that reduced nutrient loading was related to decreased aquatic weed growth in a Canadian prairie river. While some attempts have been successful, difficulties arise because the impact of the factors and their interactions on aquatic macrophyte growth differ between systems (*i.e.* lakes, rivers, reservoirs, tidal systems). With further research on interactions between abiotic factors and species autecology, life history strategies and resource allocation, manipulation of abiotic factors may become more useful as a management tool. In addition, studies of natural declines may assist in the development of conceptual models relating environmental variables to plant growth, the assessment of natural variability in aquatic plant communities and the development of realistic management goals.

4. IMPACT OF MANAGEMENT PRACTICES ON MACROPHYTE INVASIONS OR DECLINES

While most management practices aim at reducing aquatic plant abundance, it should be noted that efforts are underway in some regions to stock or preserve submerged vegetation, particularly native species. Management practices, be they positive or negative, are a disturbance to the system and can therefore affect susceptibility to invasion by opening a niche for invaders. However, as noted previously, disturbance does not necessarily lead to invasion since "pristine" areas have been invaded and not all disturbed areas have been invaded. Nichols noted that the invasion success of nuisance species appeared to increase after harvesting or herbicide treatment of native plants. However, management has also resulted in the replacement of some exotic species by native or less noxious plants. Bates noted that treatment of *Hydrilla* in Lake Seminole, Florida/Georgia, with fluridone led to the establishment of the native species *Potamogeton illinoensis* or *Chara*.

In addition to its effects on species invasions, management practices can also affect plant declines. Management may sustain exotic populations for a greater number of years than would occur without management intervention. This may relate to the failure of harvested beds to develop a herbivore community. For example, Sheldon noted that beds of *M. spicatum* in Lake Bomoseen that had been harvested for 8 years had significantly less weevils than "no-harvest" sites.

CONCLUSIONS

The environmental factors controlling aquatic macrophyte invasions differ between intercontinental invasions, where invasion success is largely determined by climate, and regional invasions, where the spread of an established exotic species throughout a region is largely a function of human activity.

At present, there is little quantitative information on the role of biotic factors (*e.g.* interspecific competition, pathogens, herbivores) in effecting species declines. In the future, biological control agents may be used to manage aquatic plant populations. However, their use will likely be limited by quarantine regulations which restrict the introduction of nonnative herbivores or pathogens.

Abiotic factors have been documented as causing declines in aquatic macrophyte communities. While few attempts have been made to modify aquatic habitats in order to prevent or reduce aquatic macrophyte growth, manipulation of abiotic factors may become a widely used management tool in the future as the role of abiotic factors in the control of natural declines is better understood.

Management practices aimed at reducing aquatic plant abundance can affect the abundance and diversity of nontarget species by promoting the establishment of desirable or nuisance plant species. Management activities may also sustain exotic plant populations for a greater number of years than would occur without management intervention.