Abstracts

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Session I

The Aquatic Ecosystem Restoration Foundation: A Unique Approach to Applied Research

Michael D. Moore, Executive Director, Aquatic Ecosystem Restoration Foundation, Lansing, MI

The first five years of the Aquatic Ecosystem Restoration Foundation (AERF) have been extremely fruitful. As one of its principle missions, the AERF sponsors research and development of environmentally sound products and methods for restoring and managing aquatic ecosystems, with a particular emphasis on selectively controlling exotic nuisance species. While these products primarily consist of aquatic herbicides and plant growth regulators, the Foundation also conducts research that integrates herbicide technologies with non-chemical control methods. It also funds studies on the biology and ecology of invasive aquatic and wetland plants that focus on the "weak points" in the life cycles of these species.

Since its inception, the Foundation has provided more than $1 million for priority research projects that have encompassed a variety of restoration and management topics. In addition, the AERF offers educational symposia on request. To date, six sessions have been held in various regions of the United States. The Foundation also sponsors academic scholarships, and facilitates dialogue and cooperation between pertinent public natural resource agencies and the private sector. To learn more about the AERF, visit our web site at http://www.aquatics.org.

Old-World Climbing Fern - Floating Islands are not Safe.

Randall K. Stocker, UF/IFAS Center for Aquatic and Invasive Plants, Gainesville, FL

Old-world climbing fern (Lygodium microphyllum) is a widespread problem weed in Old World tropics. Native to Southeast Asia, it was first described in Florida in the 1950s and is now found in thousands of acres, including floating islands of the Loxahatchee Wildlife Refuge near West Palm Beach. Herbicides can effectively control the plant, but resource managers are concerned about non-target damage in sensitive habitats. Integrating fire and herbicide programs can reduce herbicide use by half, native plant coverage increases after climbing fern removal, and removal of one highly dominant invasive plant species has resulted in only limited increases of other invasive plant species.

APIRS – Current Status and Potential New Directions

Karen Brown, University of Florida, Center for Aquatic and Invasive Plants

APIRS, the Aquatic, Wetland and Invasive Plant Information Retrieval System, now has been in operation for over 20 years. The collection contains over 51,000 annotated citations to the literature of aquatic, wetland and invasive plant science. Our mission has changed over the years from the original idea of collecting primarily control and management information on known aquatic weeds, to collecting all scientific literature on all aquatic and wetland species, and most recently, to including the scientific literature on upland invasive plants species in Florida.

We currently have the world's largest collection of scientific literature in this subject area. All of the citations in **APIRS** are annotated with categories, keywords, and plant names provided by our own staff. These citations are loaded into a fully searchable database that is available, free of charge, to anyone. It can be accessed online via our website and searched by the user, or searches can be requested from **APIRS** staff and provided by e-mail or in print. The database is used regularly by researchers, students, agency managers and others from around the globe. In exchange, users are expected to contribute reprints of their publications for inclusion in the database.

Potential new directions for **APIRS** will be presented.

Overview of the CALFED Program with an Invasive Species Perspective
Bellory Fong, Environmental Program Manager, CALFED, Sacramento, CA

Aquatic Plant Management at the City of Orlando: Its Past, Present and Future
John A. Evertsen, City of Orlando Dept. of Streets & Drainage, Orlando, FL

The City of Orlando has been involved in some aspect of Lake Management since the early 1960's. In the early 1980's we undertook numerous large-scale Lake Restoration Projects on City owned lakes. Lake Restoration at that time mainly consisted of removal of noxious plant growth and the subsequent replacement with beneficial native aquatic plants. This change in our lake shorelines required us to change our herbicide treatment techniques to insure that this work could be protected and be allowed to expand.

In the early 1990's we raised the bar again and expanded our Lake Management program to try to improve water quality with the use of submersive aquatic vegetation. This has been achieved with innovative plant, water management techniques and herbicide techniques.

NOTES

SESSION II

Weed Management and Water Scarcity; in Search of a New Paradigm

W. van Vierssen, I. H. E. Delft

Over the last decades, in many places in the world weed control has been confronted with an increasing need for environmentally sound and safe practices. The Vision on Water and the Environment presented at the recently held World Water Forum in the Hague predicts serious competition for water resources between direct human needs (drinking water), agriculture, industry and nature. To feed the growing world population, more efficient water use in agriculture and in particular irrigation through improved water management is a key issue. Re-use of agricultural (irrigation) water is one way to save water, but this is only possible if the water is not too heavily polluted. Therefore, it is predicted that in the near future a growing demand for innovative and in particular environmentally sound weed control measures will develop.

Both mechanical and biological methods qualify by their nature more for that than chemical ones. However, mechanical control is often very laborous and in the tropics serious health risks may be involved. On the other hand, manual labour through local communities clearly provides opportunities for users to participate in the cost sharing of system maintenance and will provide a certain degree of ownership of the resources, in particular in developing countries.

It is concluded that the most promising approach for the future will be integrated weed control. Integrated weed control makes use of advanced biological knowledge ranging from molecular biology to plant population and ecosystems modeling. Moreover, weed control practices will become more efficient through institutional reforms in the irrigation sector. This, however, will depend on the choice of irrigation and drainage managing agencies to introduce biological weed control systems. The latter will depend on a set of incentives related to the cost, quality and reliability of service provision and environmental regulation and policing.

Invasive *Elodea* Problems Impacting *Najas flexilis*: a Rare Native Macrophyte in Scottish Lochs

Ruth Wingfield and Kevin Murphy, University of Glasgow, Division of Environmental and Evolutionary Biology, Institute of Biomedical and Life Sciences, Glasgow, Scotland

Najas flexilis (Willd.) Rostk. & Schmidt is a submerged rooted macrophyte, which is rare in Britain and Europe, and has its European stronghold in Atlantic-coastal lochs of Scotland and Ireland. It is a red data book species and is protected under both European Union and national legislation. It occurs within a remarkably limited range of sediment and water chemistry conditions at Scottish sites. The recent invasion of freshwater lochs in the Western Isles of Scotland by *Elodea nuttallii* and *Elodea canadensis* has concerned many conservationists, as these islands contain two thirds of Britain's *Najas flexilis* populations, and a high proportion of the total number of sites in Europe at which this species occurs. Invasive *Elodea* spp share the rooted, submerged life strategy with *Najas flexilis* and appear to have a certain amount of niche congruency. However, *Elodea* spp grow faster, earlier in the growth season and can create a canopy at the water surface. These plant traits suggest that *Elodea* spp invasions could have undesirable interspecific competitive impact on native *Najas flexilis* populations, particularly in those lochs in which the plant is already experiencing stress from increased pH and/or trophic conditions. In order to provide a better understanding of the degree of threat posed by *Elodea* invasions, the plant traits possessed by plant communities containing *Najas flexilis* in Scotland have been quantified. A plant fitness measure is used to assess the fitness of *Najas flexilis* in comparison to the presence of these traits in different quantities in the plant community. The traits with the greatest effects are compared to those possessed by *Elodea* spp so that the nature of this invasive threat can be considered.

Student Paper

Trait variation in lotic macrophyte populations from Scotland and Egypt in relation to habitat conditions

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We analyzed the variation in 14 plant morphological traits from >600 plant specimens representing 90 samples drawn from a data set comprising 120 populations of 31 freshwater macrophyte (floating and submerged) species, collected from 36 sites on rivers and irrigation/ drainage channels in Scotland and Egypt. TWINSPAN classification divided the sites into 5 main groups based on variation in species assemblages. Analysis of variance of water and sediment physico-chemistry data revealed no significant between-group differences in sediment nutrient concentrations (N, P or K), underwater light regime, or water phosphate. However there were significant differences between the site-groups in terms of water pH, electrical conductivity, dissolved oxygen, total oxidized nitrogen and potassium. These differences were reflected in between-group morphological variation (for the dominant hydrophyte populations present at the component sites of the groups). Floating leaf area and biomass, and root length showed significant differences between site-groups. Sites dominated by plants with high floating leaf area and biomass, and well-ramified root systems were associated with high-conductivity, high-nutrient water conditions. High pH sites tended to be dominated by plants with low root length. Rivers with circumneutral pH, low conductivity and low nutrient status were dominated by plant populations of intermediate root length, and low to very low floating leaf area and biomass. The results provide evidence that variation in hydrophyte size and shape, across a range of species, may be functionally and consistently related to environmental conditions in flowing waters. Current river water quality biomonitoring systems which utilize macrophyte species assemblage and/or abundance information as predictor variables might be improved by incorporating information on plant size and shape variation.

Plant-Groundwater Interactions in Freshwater Wetlands: A Functional Monitoring Approach

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Variation within physiognomic characters of plants (e.g., traits related to life history, morphology, physiology or biochemistry) have been widely linked to underlying environmental parameters of the habitats in which the plants live and reproduce. Such parameters determine the intensity of stress and disturbance experienced by the plants, and place controls on the structure, and therefore functioning of vegetation. Variation in both dominant trait variables of individual plant species, and collective state variables of plant communities have been previously utilized in the classification of plant functional groups, and as predictive components of wetland functioning.

In this study a range of vegetation data was collected during field visits to permanent stations within freshwater wetland habitats across northern Britain. Data collected included measurements of a number of collective vegetation variables, and of selected traits within the dominant species. Data were also collected relating to a range of hydrological, hydrochemical, and other environmental variables for the groundwater component of the systems.

The use of multivariate techniques to investigate relationships between plant characteristics and groundwater parameters is discussed, along with the potential to develop models of eco-hydrological relationships within the wetlands studied. Such models may prove to be of value in permitting future improvement of monitoring environmental quality in such wetlands.

Student Paper

Studies for Aquatic Plant Management in Hydro Electrical Lakes in Brazil

Daniel A. S. Marcondes, Andre L. Mustafa & Robson H. Tanaka, Directorate of Environment, CESP, Dagoberto Martins, Edivaldo D. Velini & Robinson A. Pitelli, Sao Paulo State University, SP, Brazil

Aquatic Plant Survey in Hydro Electrical Lakes in Brazil

Robson H. Tanaka, Director of Environment, CESP, Dagoberto Martins, Edivaldo D. Velini & Robinson A. Pitelli, San Paul State University, SP, Brazil

Aquatic Plants and their management are being subject of several studies in Brazil due to economical and environmental impacts of excessive growth of some species. One of those studies comprises the identification of aquatic plants and their distribution along six hydro electrical reservoirs controlled by Companhia Energetica de Sao Paul (CESP). The main objective was to provide a list of species present in those reservoirs, since there is a lack of information on occurrence of aquatic plants in Brazil. CESP and Sao Paulo State University as part of an agreement program conducted inspections between October 1998 and April 1999. We identified 30 species: 16 emergent, 6 submersed, 5 floating and 3 emergent with floating leaves ones. Weed communities were classified in levels according to the size and the species composition. The six reservoirs present great differences in size, age and water quality and the species distribution depends on the characteristics of each reservoir. Besides that, some species (*Eichhornia crassipes*, *Salvinia molesta* and *Polygonum spp.*) were found in all reservoirs. Submersed species like *Egeria densa*, *E. najas*, *Ceratophyllum demersum* were not found in some reservoirs, but developed dense stands in others. Samples of three of the most invasive species (*Egeria densa*, *Egeria najas* and *Eichhornia crassipes*) were collected and will be used to evaluate differences between biotypes with Random Amplified Polymorphic DNA (RAPD) analysis, since these species are considered to be native in the region. The results of this analysis will be considered in aquatic weed control studies.

Keywords: *Egeria densa*; *Egeria najas*; *Eichhornia crassipes*; CESP, UNESP; RAPD.

Macrophytes Population Changes in Santana Reservoir, Rio de Janeiro, Brazil. Five Years of History.

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Santana reservoir was constructed in the 50th aiming to produce hydropower energy to Rio de Janeiro City. The water came partially from the Piraí river but the most important contribution is from the water pumped from the Paraíba river, extremely eutrofized. One year after the reservoir was fulfilled, the *Eichhornia crassipes*, *Pistia stratriotes*, and *Salvinia* spp infestations were high and promoted a great interference in the hydropower plant and started other problems related to aquatic weeds, like us mosquitoes and human diseases. The first control procedure was hand removal, which obviously did not take much time to prove unsuccessful. In the early 60th, the chemical control was began with extensive use of 2,4-D (DMA6-BR) showing very good results controlling *E. crassipes, Eichhornia azurea* and broadleaf macrophytes. The recurrent use of these herbicides promoted a significant shifting in the aquatic weed composition, leading the predominance of some grasses, mainly *Echinochloa polystachya, Panicum repens, Paspalum repens* and *Brachiaria mútica*. The establishments of these populations were promoted the herbicide use and the sedimentation of solid residues delivered by Rio Paraíba water. The chemical control was discontinued at the end of the 60th. After that some broadleaf weed populations increased and the reservoir was occupied by a highly diversified macrophytes community. In 1975, a harvest machines was develop to work in the Santana conditions: a backhoe machine was adapted on a boat with paddwehells. This backhoe collected the aquatic weeds and release in the water stream. The weeds were stopped by a floating barrier, dragged into a truck and delivered to a biomass disposal area. This process was very efficient, but also promoted a weed shifting. Nowadays, the weed communities partially are a consequence of mechanical harvest and there is clear a population succession after the weed control. The first populations that come-up are *Cyperus* spp, *Saggitaria montevidensis, Myriophyllum aquaticum* and *Egeria densa*. These populations are like pioneers and promote the sediment fixation. In the next population flow, *Heteranthera reniformis, Alternanthera philoxeroides, Pontederia* spp are predominant. Almost one year after the macrophytes harvesting, *Typha* spp, *E. azurea*, *Panicum rivulare, Polygonum* spp, *Brachiaria arrecta, Brachiaria mutica,* and *Ludwigia* spp develop dense populations in shallow areas and *Egeria densa*, *Eichhornia crassipes* and *Pistia stratiotes* are important in deep waters. This succession cycle takes about two years. The introduction of *Brachiaria arrecta* and *Egeria densa* in the last decade, brought a great problem to this control system: these weeds are not stopped by the floating barrier reaching the protection screen of the pumping station, promoting a great additional labor and cost. The use of grasscarp was tested twice but unsuccessfully, mainly due the water quality and animal management.

Managing Excessive Aquatic Plant Growth in a Lake Down-Under, Build it and They Shall Proliferate

Danny Roberts, Geoff Sainty, Sharon Cummins and Geoff Hunter, Sainty & Associates, Lars Anderson, NSW Australia, and Lars Anderson, USDA UC-Davis, Davis, CA

The Sydney International Regatta Centre is a $A40 million dollar facility located at Penrith NSW, Australia. It consists of two interconnected shallow lakes, with a capacity of around 2000 megalitres. The rowing lake is 2.3 km long and 170 m wide and has a maximum depth of 5.5m whilst the warm-up lake has an average depth of 3m and a convoluted shoreline. The two lakes are used for training and rowing events up to and during the Sydney 2000 Olympic games and form the rowing heart of Sydney. Adjoining these two lakes and drawing its water from them is the white water slalom course for the Olympics. When the rowing course was originally constructed, the lakes were planted with ribbonweed *Vallisneria americana* var. *americana* (Michaux), with the intent to establish a basis for a healthy aquatic plant assemblage, which was capable of "out-competing" invasive macrophyte species and nuisance blue-green algae. Over the past few years, the aquatic plant assemblages have flourished, with six additional native species colonizing the lakes. In March 1997, ribbonweed began to break away at its base and float to the surface. This defoliation caused major problems for management of the lakes and its primary users, as floating leaves interfered with rowing and swimming events. To alleviate the problem, ribbonweed was physically removed and mechanical harvesting has been the primary management tool used to keep the plants under control. A program of monitoring was established in 1997, where spatial and temporal patterns in the distribution and abundance of submerged aquatic macrophytes were measured over two years. This program found that harvesting was ineffective, in terms of keeping plant biomass to a manageable level. In this paper we report the results of the monitoring program and present some preliminary data on a management experiment, which used the herbicide fluridone to help reduce plant growth in conjunction with physical and mechanical removal.

Managing Stormwater Runoff with an Off-line Wetland Treatment System.

Geoff Sainty, Saint and Associates, PTY Ltd., Geoff Hunter, Hunter Environmental Services, Jerome Allchin, & David Bluett, Business Land Group, and David Hunt, David Hunt & Associates, Pty Ltd., NSW Australia

Natural wetlands have been described as "Nature's Kidneys". Their ability to polish wastewater has long been recognized and this ability has been used in recent times to manage and treat stormwater. The results have been variable. Construction, due to site constraints, is generally in stream, resulting in damage to the macrophytes in the wetland, re-mobilization of sediment and often the loss of the wetland's ability to treat stormwater.

Unlike wastewater, where flow rate and loading rate can be controlled, stormwater has variable flow rates and variable pollutant concentrations. Catchment management practices, such as source and at source controls, which have the potential to provide some runoff control, are often neglected in favor of "end-of-line" solutions, such as a gross pollutant trap or constructed wetland.

Constructing the Wetland Treatment System "off-line" from the watercourse provides the opportunity to control the flows entering the wetland. Such a design strategy allows flexibility to better regulate the inflows, into the wetland, to coincide with maintenance, high or low rainfall, weed control, de-silting, habitat enhancement, plant establishment, access etc.

An "off-line" Wetland Treatment System has been designed and constructed at Chullora, an inner western suburb of Sydney, NSW Australia. Details of the design, construction and management of this wetland system are provided in this paper.

Alligator Weed: Tasty Vegetable in Australian Backyards

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The discovery of the present distribution of alligator weed (*Alternanthera philoxeroides*) in Australia is cause for considerable concern, earning it a place among the top 20 weeds of National Significance. It is considered one of the worst aquatic and terrestrial weeds in the world. In all Australian states, the weed is cultivated as a green leafy vegetable by the local Sri Lankan community, in the mistaken belief that it is another plant (*Alternanthera sessilis*), very popular in Sri Lanka. The Department of Natural Resources and Environment in Victoria, Australia embarked on an innovative community-department partnership with the Sri Lankan community to eradicate, manage and prevent reinfestation of alligator weed. The main priorities of the plan were to identify the problem, raise public awareness, and develop an eradication plan. The program also sought to identify and introduce acceptable alternative for the Sri Lankan community. As results of this program, 775 alligator weed infestations have been located including 12 naturalized sites. Four herbicides were tested as an experimental basis in backyards. More than 600 infestations were treated using Dichlobenil, Glyphosate and Metsulfuron methyl. Results showed that dichlobenil at the rate of 60kg ha^{-1} were a suitable herbicide in backyard situations. One Australian native species (*Alternanthera denticulate*) was selected tested for nutritional value and distributed to Sri Lankan families. The new vegetable appears to be very popular and now sold by 25 shops around Melbourne in Australia.

Evaluation of New Herbicides for the Control of Submerged Weeds in New Zealand

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The exotic submerged species, *Lagarosiphon major*, *Ceratophyllum demersum*, *Egeria densa*, and *Hydrilla verticillata*, are causing localized problems in lakes, reservoirs, and rivers in New Zealand. However, the aquatic herbicide diquat is the only product registered in New Zealand for controlling these and other submerged plants. Since diquat has proven to be ineffective in controlling all submerged weeds under some environmental conditions, recent small-scale trials have been conducted to evaluate the potential of the herbicides, triclopyr, dichlobenil and endothall to control the aforementioned target weeds. In addition to target weed efficacy, these trials were used to evaluate the impacts on preferred native species of *Potamogeton, Myriophyllum* and charophytes when using these products. Promising results with endothall to control *C. demersum, L. major* and *H. verticillata* have led to further studies to evaluate the potential of endothall for selective submerged weed control in comparison with diquat, particularly in turbid conditions where diquat is less efficacious.

Lake Victoria Regional Water Hyacinth Management Program

Dick Nyeko, Ministry of Agriculture, Entebbe, Uganda, Thomas J. McNabb, Clean Lakes, Inc., Martinez, CA, Thomas G. Moorhouse, Clean Lakes, Inc., Kampala

The Management of Giant Hogweed (*Heracleum Mantegazzianum*) in an Irish River Catchment

Joseph M. Caffrey, Central Fisheries Board, Dublin, Ireland.

Heracleum mantegazzianum is an alien plant that was introduced to Ireland as an ornamental in the late 19th Century. The banksides of rivers and streams are the preferred habitat for the plant and it is now a feature in many important angling catchments. The continued spread of this plant is a cause of concern because of its impact on human health and on the ecology of infested river corridors. As *H. mantegazzianum* populations can only be perpetuated via seeds, most control strategies aim to limit recruitment to future generations and to deplete the seed bank reserve. Trials conducted in Ireland and in Europe have revealed the sensitivity of the plant to glyphosate. Based on research conducted in Ireland a four-year treatment programme, using glyphosate, was formulated. This must be operated at a catchment level if the risk of reinfestation from within the catchment is to be minimised. Prior to 1998 no co-ordinated attempt to eradicate *H. mantegazzianum* from a catchment had been undertaken. To investigate the feasibility, and logistics, of managing this hazardous plant in a discrete river catchment, a control programme on the Mulkear River catchment (670 km^2) was undertaken by the Office of Public Works. Field surveys indicated that an area of *circa* 35 km^2 within the catchment was overgrown with *H. mantegazzianum*. Weed treatment commenced in March 1998 and continued through 1999 and 2000. With three of the four-year treatment schedule complete, the preliminary results are very encouraging. These will be presented. The benefits to the local community and the overall ecology of the river and riparian habitats will be discussed.

Introduction and Release of the Alligatorweed Flea Beetle, *Agasicles hyrgrophila* in Puerto Rico

Edwin Abreu, and Nelson Semidey, Crop Protection Dept., University of Puerto Rico, and Lourdes Bernier' Dept. of Natural Resources & Environment, Puerto Rico

The aquatic weed control program began in Puerto Rico in 1980, with matching funds from the local government and the U.S. Army Corps of Engineers. The program was based on the use of aquatic herbicides. The waterway acreage infested by weeds in Puerto Rico was 912 acres with annual control expenditures of $352,000. The first attempt to use biological control was initiated in 1980 was discontinued the same year due to shortage of funding. The effort was to introduce the water hyacinth weevil, *Neochetina eichhorniae*. Use of biological control agents was reinitiated in 1996 in cooperation with U.S. Corps of Engineers, Department of Natural Resources and Environment and the University of Puerto Rico. The target weed plant selected for the present study was the alligator weed, *Althernanthera phylloxeroides* and the biological agent for control is the alligatorweed flea beetle (AFB), *Agasicles hygrophila*. Quarantine facilities were built for the introduction of this insect to Puerto Rico, which was received in June 1997 and placed in the quarantine laboratory (QL). Additional host preference tests were conducted. Insect population numbers were increased in the QL and moved to a 300 gallon covered pond (covered was built with an insect proof screen cage) to further increase population numbers. The AFB was released in July 1-2 in Hondo River in Toa Baja (northern coast) and in the Majagual Creek in Mayaguez (western coast). Additional releases were done during the year for a total of 3,908 and 1,127 AFB, respectively. The insect has established itself in both areas and the alligatorweed has been controlled by the insect. The weed was substituted by the duckweed, *Lemna sp.* and the waterhyacinth, *Eichhornia crassipes*. The area infested by alligatorweed was reduced and plant density was also reduced from 167 stems/0.5 m^2 to 18 stems/0.5 m^2 on samples. Also adult insect population ranged from 1.5 to 6 insects/ft^2 in the feeded areas controlled by AFB. Efforts are continuing to disperse the AFB to other weed infested areas. Future plans of the project include introduction and release of the water lettuce weevil, *Neohydronomus affinis*, for the control of the water lettuce, *Pistia stratiotes*, the second important damaging aquatic weed in Puerto Rico.

NOTES

SESSION III

Isolation and Characterization of Bioactive Compounds from *Typha domingesis*

Dean F. Martin and Maria T. Gallardo-Willaims, University of South Florida, Tampa, FL, and Cherie L. Geiger, University of Central FL, Orlando, FL

The bioavailability of phytotoxins plays an important role in establishing their ecological significance. We have been able to isolate several bioactive secondary metabolites from aqueous extracts and leachates of *Typha domingesis*. Our separation protocol involved the use of activated charcoal as a solid-phase support for organic compounds and successive extraction with organic solvents, followed by analysis using GC/MS. The materials that we isolated are fatty acids and phenolic compounds with know phytotoxic activity. Both the extracts and the phytotoxins have the potential for inhibiting the growth and chlorophyll production of several ecologically relevant species. The observed phytotoxic effects are in good agreement with a proposed mathematical model for allelopathic compounds.

Removal of Aqueous Selenium by Four Aquatic Plants

Kathleen M. Carvalho and Dean F. Martin, Institute of Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL

Several aquatic plants were examined for as potential phytoremoval agents for selenium in aqueous solutions. Selenium was initially present in concentrations of 0 –100 ppm Se (as sodium selenite) in 10% Hoagland's medium, and aquatic plants were grown in the medium for one week. Four aquatic plants were studied: Cattail (*Typha domingensis*), duckweed (*Lemna obscura*), hydrilla (*Hydrilla verticillata* Royle), and swamp lily (*Crinum americanum*). Analyses were done by atomic absorption spectrometry using hydride reduction. Four replications were done. Each system was examined for change in fresh weight, percent removal of selenium from solution, and accumulations of selenium in the plant. At selenium concentrations of 100 ppm or less, fairly good to excellent removal was achieved (65 – 100%), depending on the plant. Exposure to concentrations greater than 100 ppm had an inhibitory effect on plant growth, so concentrations less than 100 were studied in more detail. During a one-week period, hydrilla quantitatively removed the selenium, and the fresh and dry weights of the plants increased. Other plants were less effective in removal or were more affected by selenium.

Student Paper

Effect of Water Depth on Torpedograss Establishment

Dian Smith, and Michael Smart, U. S. Army Engineer Research and Development Center, LAERF, Lewisville, TX and Charles Hanlon, South Florida Water Management District, West Palm Beach, FL

Lake Okeechobee, a 173,200ha shallow subtropical lake located in south Florida, has recently been invaded by torpedograss (Panicum repens), which is an exotic, terrestrial species that was intentionally introduced to Florida in the early 1900s. Since the 1970s, an estimated 6,400ha of the lake's native plants, such as spikerush (Eleocharis cellulosa), have been displaced due to the torpedograss invasion. Based on field observations, torpedograss distribution within the marsh is greatest at higher elevations where water depth averages 50cm; however, the species has been observed in deeper water. In the first part of a two-year study, the ability of torpedograss to establish at depth was evaluated. Experimental pond studies revealed that fragments remain buoyant for extended periods and so facilitate the dispersal of torpedograss within the lake. If fragments become anchored or attached to exposed sediment, they can readily root and establish into mature plants. In this manner, low water periods contribute to an expansion of torpedograss in the lake. Once well established, torpedograss can thrive in depths of 75cm or less and can survive even deeper inundations. These findings explain the dispersal and colonization patterns of torpedograss within the lake. When coupled with lake elevation data, these findings suggest that low water levels or drawdowns would increase the marsh area susceptible to torpedograss invasion.

Traits of Four Submersed Aquatic Macrophyte Species: Effects on Resources, Environmental Conditions and Resilience after Clipping and Drought Disturbances

Katharina A. M. Engelhardt, John A. Kadlec, Utah State University, Department of Fisheries and Wildlife, Logan, UT

We studied morphological and functional traits of four native submersed aquatic macrophyte species (*Potamogeton pectinatus*, *P. nodosus*, *P. crispus*, and *Zannichellia palustris*) in an outdoor mesocosm experiment to understand how species differ in their morpholigical and functional traits and how they might affect wetland ecosystems functioning. We also subjected the species to a clipping and a drought disturbance to understand how the species recover from the disturbances. Above- and below-ground biomass, root-to-shoot ratios, and occupation of above-ground space were significantly different among species. All species significantly decreased temperature and alkalinity of the water column compared to an unplanted treatment, and species varied significantly in their effects on nitrogen availability in soil interstitial water and surface water, light supply under the species' canopies, pH of the soil and water, and metaphyton production. Species also differed in their responses to clipping and drought. We conclude that species' effects on the environment and species' responses to the environment need to be studied rigorously in aquatic macrophytes to understand how macrophyte species and communities can affect wetland ecosystem functioning. This information is vital in the conservation, restoration, and creation of functioning wetland ecosystems.

Student Paper

Simulation of Potential Persistence of Sago Pondweed and American Wildcelery in Peoria Lake, Illinois, Using Recent and Historical Data on Light Availability and Suspended Sediments
(WU 33128)

Elly P. H. Best and William A. Boyd, U. S. Army Engineer Research and Development Center, Vicksburg, MS, and William F. James, U. S. Army Engineer Research and Development Center, Environmental Laboratory, Eau Galle Aquatic Ecosystem Research Facility, Spring Valley, WI

Simulation models for two submersed plant species, representing the characteristic life forms of submersed aquatic vegetation in the Upper Mississippi River System, notably sago pondweed, a canopy former and American Wildcelery, a non-canopy former, have been developed. These models were used to explore the habitat quality required for the persistence of both plant species in Peoria Lake, Illinois. Relationships between extinction coefficient, Secchi depth, turbidity and total dissolved and suspended solids concentrations in the water column used to run the model were derived by regression of historical and recent data of Peoria Lake. Simulations indicated that American wildcelery can persist in the lake at a rooting depth of 0.5 –1.0 m, provided the light extinction coefficient of the water column is on the order of 2.5 m^{-1}. This situation can only occur at total suspended sediment concentrations of about 10 mg L^{-1} or less. Sago pondweed can persist at somewhat higher suspended sediment concentrations. The results of the model explorations can be used to modify existing river management practice, and to implement operational scenarios aimed at conserving/optimizing submersed aquatic vegetation.

Economic Value of Aquatic Vegetation to Fisheries (WU 33307)

James P. Kirk and Jim E. Henderson, U. S. Army Engineer Research and Development Center, Vicksburg, MS

Work has been initiated to evaluate the economic importance of aquatic vegetation to fisheries and related water uses in large impoundments. To date, three major reservoirs have been located where adequate and comparable angler creel surveys are planned or in progress. Expenditures by anglers will be determined through a statistically-efficient angler creel survey on reservoirs where aquatic vegetation affects the quality of angling. Trip expenditures will be linked to changes in aquatic vegetation. This information will then be utilized to estimate total economic value of angling to the local economy. Data will be collected to estimate economic impacts of aquatic vegetation on property owners, boaters, waterfowl users, and power generation. Taken together, this information should allow managers to evaluate the return on their expenditures in aquatic plant management.

Effects of Hypoxia on Fish Distribution in Vegetated Habitats (WU 32944)

K. Jack Killgore and Jan Jeffrey Hoover, U. S. Army Engineer Research and Development Center, Vicksburg, MS

Hypoxia is characteristic of densely vegetated habitats. Rates of growth, activity, and distribution of fish are limited by low dissolved oxygen (DO). Thus, one benefit of plant control is mitigating low DO. We evaluated fish distribution relative to DO concentrations in Mercer Bayou located in southwest Arkansas. Mercer Bayou has extensive aquatic vegetation including alligatorweed, waterhyacinth, American lotus, coontail, duckweed, and azolla. Sampling stations were distributed among three reaches that varied in DO concentrations ranging from 0.2-7.7 mg/l. Hypoxia was pronounced at the downstream reach of the Bayou because of stagnant water and nearly complete shading of the water's surface by floating plants. Fishes were sampled in each reach by seining and gill netting. Forty-five fish species were collected and the community was dominated by phytophilic taxa. In upper and middle reaches, species richness was relatively high (>13 species). In the lower hypoxic reach, species richness was low (< 8 species). Polynomial regression indicated a significant positive correlation ($R^2 = 0.80$) between species richness (y) and DO (x): $y = 6.53 + 8.511x - 0.86x^2$. Gars, topminnows, and small backwater species (29% of all species documented) persist at low DO, but most sunfishes, darters, and larger benthic fishes avoid hypoxic waters probably due to physiological limitations. Species adapted for aerial and surface film respiration dominate the fish assemblage in hypoxic waters. Our model suggests that dissolved oxygen can be used to predict fish species distribution and quantify habitat quality in vegetated areas.

Selection and Use of Aquatic Vegetation by Migratory Waterfowl in North Central Texas

JoEtta K. Smith, Robert D. Doyle & Ken L. Dickson, University of North Texas, Denton, TX, Gary O. Dick, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

North American waterfowl research has predominately focused on the Northern prairie pothole region which comprises the breeding range. In recent years, with diminishing natural wetlands and in increase in manmade impoundments, the importance of quality migratory and wintering habitat has been realized. Research on Southern waterfowl habitat is sparse, and Northern plant assemblages although extensively studied, differ, as do waterfowl needs. Waterfowl shift from a high protein diet in their summer range to a high carbohydrate diet in winter to increase lipid reserves for the stress of migration, nesting and molting. A main source of this high carbohydrate diet is aquatic plants.

Assessment of aquatic plant selection by waterfowl on 49 0.2ha. research ponds has been conducted for three winters (1997-2000). Ponds were categorized by dominant plant species as either mixed native, flooded terrestrial, Hydrilla, Eurasian watermilfoil, native/Hydrilla mixed, native/milfoil mixed or salvinia. Census with waterfowl species identification were performed to investigate possible impacts of exotic aquatic vegetation on waterfowl. Peak duck migration occurred in January each year with a secondary peak in early December. Eighteen waterfowl species were observed. Our study also included correlation analysis between pond water levels and waterfowl use. Time activity budgets were conducted in spring 2000 on mixed native and Hydrilla ponds to compare waterfowl time partitioning on native aquatic vegetation versus Hydrilla.

Student Paper

NOTES

SESSION IV

The Resilience of Rhizomes: a Case-Study of Pickerelweed.

Alison Fox, University of Florida / IFAS, Gainesville, FL.

Research has been conducted on the population biology, native herbivore load, and responses to damage of the native emergent plant Pickerelweed (Pontederia cordata). These studies are intended to allow us to identify the potential impacts of non-target damage on pickerelweed from new, biological control agents that might be introduced for waterhyacinth that may not be completely host-specific. In long-term field trials to assess the response of populations of pickerelweed to removal of various amounts of leaf biomass the only significant reductions in plant density and biomass compared to the controls were in the two most severe treatments applied at the most frequent times (removal of 80% of leaf biomass every 1 or 3 months), most of which were applied underwater. Populations of pickerelweed in all other treatments (including those with monthly removals of 20 to 30 % of leaf biomass) were not reduced. The resilience of pickerelweed to tissue loss has been impressive. Similar trials on isolated plants in tank studies showed that rhizomes continued to grow even when 80% of the leaf biomass was removed biweekly over two months. Pickerelweed productivity has been quantified in the field and has been correlated with season and water level. Leaf turnover data have provided estimates of organic matter deposition rates, an important consideration in fisheries restoration sites. An inventory of native herbivores and other associated insects is being continued, but remarkably little consistent damage has been observed that significantly reduces plant productivity.

Predicting the Sprouting of Hydrilla Turions and Tubers in Clear Lake, California

David Spencer and Gregory Ksander, USDA-ARS Exotic and Invasive Weed Research Unit, Weed Science Program - Robbins Hall, Davis, CA

Sprouting of monoecious hydrilla (*Hydrilla verticillata* L. f. Royle) turions and tubers was estimated using previously developed equations relating sprouting to accumulated degree-days. Sediment temperatures at three depths and two sites in Clear Lake, California were recorded between August 1997 and August 1999. Water temperatures about 0.3 m above the sediment surface were recorded at five additional sites from March 1998 to August 1999. Sediment temperature data at one site were used to calculate accumulated degree-days. There was good agreement between sprouting predictions and field survey data on the presence of hydrilla in weed rake casts. Small differences among water temperatures at the five sites and strong relationships between water and sediment temperatures indicate that sprouting should be similar in hydrilla beds found along the western and southern shores of upper Clear Lake. These results are useful in selecting timing for surveys of hydrilla abundance and the application of hydrilla management techniques.

Nonchemical Alternatives for Weed Control in Oregon Irrigation Canals

Mark Sytsma, Environmental Biology, Portland State University, Portland OR, and Michael Parker, Biology Department, Southern Oregon University, Ashland OR

Nonchemical alternatives for weed control in a southern Oregon irrigation canal were investigated following a fish kill caused by the spill of herbicide-treated water a stream. Sediment removal, shading, sediment amendment, alteration of canal morphology, and triploid grass carp were evaluated in 1998 and 1999.

Sediment removal resulted in significant reduction in Sago pondweed biomass. The coefficient of variation of sediment depth and plant biomass was greater in sediment removal plots. Incomplete sediment removal caused an increase in "patchiness" of sediment and plants. Failure to evenly and completely remove accumulated sediment in the canal reduced efficacy of sediment removal for aquatic plant control. Reduction in canal width to increase current velocity and reduce sediment accumulation resulted in higher plant biomass than in "control" sections that were not narrowed. Increased biomass in the narrow sections, despite a substantial reduction in sediment depth and accumulation, may have effectively buried the sprouting plants, preventing their emergence.

Sediment amendment with barley straw during winter drawdown of the canals resulted in virtual elimination of Sago pondweed from treatment plots the following summer. Straw washed from the plots when the canal was rewatered in the spring, which clogged screens downstream from the plots, however, weed control the following summer was excellent. Amendment of the canal sediments with acetic acid during winter drawdown in a container experiment also resulted in a significant reduction in Sago pondweed biomass the following summer.

Shading of the canal with neutral-density cloth also reduced plant growth. In mid-July, biomass in the 80%-shade plots was 15% of unshaded plots. Plant growth was reduced by 50% in 26% and 55% shade treatments. Measurement of shade produced by riparian vegetation provided 32 to 95% reduction in incident light, which suggest that native vegetation may be effective in reducing plant biomass in canals in some situations.

Triploid grass carp were stocked at 46 and 87 kg/ha in two 600 m canal sections in 1999. Sago pondweed biomass was consistently lower and the biomass of exported plant fragments was higher in the canal section with the higher stocking rate. Plant biomass was not controlled adequately, however, and mechanical treatment was necessary in the stocked canal sections to maintain adequate water delivery. Failure of the fish to control vegetation was attributed to unseasonable cool water temperatures early in the irrigation season. Through mid-July, minimum daily water temperatures were consistently below 12 C.

The results suggest that an integrated management strategy that includes measures to reduce plant production, such as sediment amendment and shading, and a grass carp stocking program that is keyed to water temperature and not irrigation season would be most effective in controlling Sago pondweed.

Operation Biological Control at the Aquatic Plant Control Operations Support Center (APCOSC) in the Jacksonville District

Charles E. Ashton, U. S. Army Corps of Engineers, Jacksonville FL

A slide presentation and discussion of operational biological control at APCOSC in the Jacksonville District will be presented. The center makes yearly field collections and ships insect biological control agents throughout the southeastern United States and Puerto Rico for the control of alligator weed. Opportunities to integrate biological control with chemical control will also be discussed.

Triploid Grass Carp: A Review of the Imperial Irrigation District's Biological Program

Lupe Castro, Imperial Irrigation District, Imperial Valley, CA

The successful use of triploid grass carp (Ctenopharyngodon idella) in the canals and reservoirs of the Imperial Irrigation District (District) was spawned from research aimed at eradicating the aquatic macrophyte – hydrilla (Hydrilla verticillata) from the Imperial Valley. Hydrilla, first found in the Valley in 1977, soon infested over 600 miles of irrigation canals. A research team, formed n 1981 to study various methods (mechanical, chemical, and biological) of eradicating hydrilla, determined that while an integrated approach would be utilized, triploid grass carp would be the "main" weapon. In 1985, the District received permission from the California Department of Fish and Game Commission to operationally stock its canals. The District's continued need for triploid grass carp, not only for hydrilla eradication but for general weed control, coupled with importation restrictions lead to the construction of the District's own grass carp hatchery in 1988. Since 1985, over 240.000 grass carp have been stocked into the waters of the Imperial Valley and the hydrilla biomass has been reduced by over 99.9%.

Biology and Control of Limnophila

W. T. Haller, University of Florida, Center for Aquatic and Invasive Plants, Gainesville, FL

In 1980, Mahler wrote an article in AQUATICS magazine entitled "Limnophila – a new exotic pest." He reported that this species, *Limnnophila sessiliflora* was first reported in Florida in 1971 and by 1980 was found throughout the state. He also noted that the plant was not controlled by "generally accepted control measures." Limnophiila has continued to steadily increase in locations and coverage in Florida. In the past 20 years most acceptable control has been attained by allowing the plant to "emerge" from the water and treat with Banvel 720 or low volatile esters of 2,4-D. It is necessary, in this manner that the plant has to clog a waterway and emerge before acceptable control can be attained. Since 1996, we have extensively tested fluridone, Copper diquat; and conducted limited trials with 2,4-D granular, and endothal, and have yet to test tryclopyr. To date, best results have been attained with a unique application method utilizing diquat.

Salvinia Molesta in Alabama-The First Year Story

Joe Zolczynski, Alabama Division of Wildlife and Freshwater Fisheries, Spanish Fort, AL

Giant salvinia, *Salvinia molesta*, was first documented in Alabama in a single seven-acre pond in the Alabama river drainage. The Alabama Division of Wildlife and Freshwater Fisheries did not become aware of this infestation until July, 1999. Surveys were initiated immediately to determine if giant salvinia was present in any other bodies of water. Salvinia was subsequently found in one other pond in the Alabama River drainage directly downstream from the initial infestation and in two ponds in the Chattahoochee River drainage. Cooperative working agreements were formed among the Alabama Division of Wildlife and Freshwater Fisheries, Alabama Power Company, and the Mobile District, U.S. Army Corps of Engineers, for the purpose of removing giant salvinia from these ponds.

These agreements and work performed to control giant salvinia are discussed.

NOTES

SESSION V

Small-scale Herbicide Evaluations Against Giant Salvinia (WU 32437)

Linda S. Nelson and Kurt D. Getsinger, U. S. Army Engineer Research and Development Center, Vicksburg, MS, John G. Skogerboe, U. S. Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

Giant salvinia (*Salvinia molesta* D.S. Mitchell) is a free-floating, aquatic fern native to Brazil that has recently established and become a nuisance in many lakes, rivers and reservoirs in the United States. Giant salvinia is considered one of the world's worst weeds due to its prolific growth habit, effective means of distribution and difficulty of control. Current information on the use of herbicides to manage this exotic weed is limited. An outdoor tank study was conducted at the Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX to assess the efficacy of the following treatments against giant salvinia: Aquathol K, Hydrothol 191, Reward, Rodeo, Arsenal, Komeen, Arsenal + Rodeo, Hydrothol 191 + Rodeo, and Reward + Komeen, Reward + Aquathol K, Reward + Hydrothol 191. Type of surfactant, rate of application and application technique were varied. Treatment with 4.7 L ha^{-1} Reward, 18.7 L ha^{-1} Rodeo, and all of the herbicide combinations controlled $\geq$ 98% salvinia 42 days after treatment. Reward was the most effective herbicide; controlling salvinia regardless of rate, surfactant, application method (submersed vs. foliar application) and whether or not Hydrothol 191, Aquathol K or Komeen were included in the spray mixture. The least effective product evaluated against salvinia was Arsenal.

Aquatic Vegetation Control in Irrigation Conveyance Systems and Treatment Results on *Salvinia molesta* with Clearigate Aquatic Herbicide.

Paul Westcott, Applied Biochemists, Laporte Water Technologies, Inc., Phoenix, AZ

Submerged aquatic vegetation can adversely affect the delivery of water through irrigation canals, ditches, and laterals. There are a limited number of products labeled for controlling aquatic growth in moving water systems and some of these present unacceptable water use restrictions or potential hazards to the applicator. Clearigate is a non-restricted use, broad-spectrum aquatic herbicide/algaecide. Clearigate is labeled for use in crop and non-crop irrigation conveyance systems, potable water reservoirs, lakes, farm, golf course, industrial, and swimming ponds. Clearigate imposes no water use restrictions during or after application. Clearigate is a chelated copper formulation containing an emulsified surfactant/penetrant to enhance uptake into plant tissue. Control of Sago Pondweed (Potamogeton pectinatus) in irrigation canals can be achieved by applying Clearigate at 1 PPM copper for a contact period of 3 to 4 hours. A variety of application techniques may be employed with Clearigate including metering pumps, gravity drip systems, and conventional spray equipment.

Treatment of Salvinia molesta with Clearigate has shown to be a highly effective control method against this invasive species. In situations where silty water, water use restrictions following treatment, or risk of damage to adjacent, non-target species may limit the use of other herbicides, Clearigate may be the best choice.

Effects of Water and Copper Complexes in Combination with Reward Herbicide

Steven J. Kammerer , Zeneca Professional Products, St. Augustine, FL

A wide array of various copper algaecides and herbicides have been developed and are now marketed by several manufacturers for the aquatics market. Reward herbicide, manufactured by Zeneca AG Inc., is often used in combination with a copper material to enhance algae or herbicidal activity against target aquatic nuisance plant species. The trend among aquatic plant managers is to use as little water as possible in subsurface applications to maximize time savings involved with mixing and loading herbicides and water. Some instances of chemical incompatibilities between Reward and one of the newer aquatic copper herbicides have been reported recently. Zeneca conducted a large compatibility trial evaluating Reward compatibility in full concentration with eight different copper materials along with compatibility testing in distilled water, hard water, alkaline and acidic water. Results of these studies will be presented

Evaluations of Aquathol K Combined with Reward, Cutrine-Plus, and Hydrothol 191 for Improved Control of Hydrilla (WU 33304)

Toni G. Pennington, Aquatic Ecosystem Restoration Foundation, Flint, MI, and John G. Skogerboe, U. S. Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

A greenhouse study was conducted to evaluate combinations of herbicides and copper for improved control of hydrilla (*Hydrilla verticillata* (L.f.) Royle). Varying concentrations of Aquathol K (dipotassium salt of endothall) used singularly and in combination with Hydrothol 191 (dimethylalkylamine salt of endothall), Cutrine-Plus (chelated copper), or Reward (diquat) were applied to hydrilla grown in 50-L aquaria. Herbicide/copper combinations were applied using a 24-hour dissipation half-life and shoot biomass was used to determine efficacy at 3 and 6 weeks after treatment. The lowest combination rates of Aquathol K (1 mg/L active ingredient (ai) endothall) + Cutrine-Plus (0.5 mg/L ai copper) and Aquathol K (1 mg/L ai endothall) + Reward (0.5 mg/L ai diquat dibromide) provided 95 to 100% control, similar to the maximum rate of Aquathol K (3.0 mg/L ai endothall) applied alone. Aquathol K combined with Hydrothol 191 did not significantly improve hydrilla control compared to products used alone.

Field Demonstration of Aquathol K Combined with Reward, Cutrine-Plus, and Hydrothol 191 for Improved Control of Hydrilla (WU 33304)

Toni G. Pennington, Aquatic Ecosystem Restoration Foundation, Flint, MI, John G. Skogerboe, U. S. Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX.

A large-scale demonstration was conducted on Toledo Bend Reservoir, Louisiana to evaluate herbicide/copper combinations for improved control of hydrilla (*Hydrilla verticillata* (L.f.) Royle). Herbicide treatments, based on small-scale studies, included Aquathol K (dipotassium salt of endothall) applied alone and in combinations with Cutrine-Plus (chelated copper), Hydrothol 191 (dimethylalkylamine salt of endothall), or Reward (diquat dibromide) to eight, two-hectare plots. Applications were conducted on 8 and 9 September 1999, when hydrilla biomass was at its peak, topped out, and coated with algae (worst case). Data collected included pre and post treatment water quality data and shoot biomass, and exposure times using rhodamine WT dye. The lowest combination rates of Aquathol K (1 mg/L active ingredient (ai) endothall) + Cutrine-Plus (0.5 mg/L ai copper) and Aquathol K (1.5 mg/L ai endothall) + Reward (1 gal/acre, $\simeq$ 0.25 mg/L ai diquat) resulted in 90 to 95% control of hydrilla. The lowest combination rates provided slightly better control than higher rates, probably due to longer exposure times. Improvements in water quality were indicated by increases in dissolved oxygen concentrations in treated plots compared to the untreated reference plot.

Estimating Exchange Flows and Herbicide Transport in a Shallow Lake

Sveinn Ó. Palmarsson and S. Geoffrey Schladow, University of California, Davis, CA, Lars W. J. Anderson, USDA-ARS, Exotic and Invasive Weed Research, University of California, Davis, CA

Near shore water currents were quantified to assess the potential transport of herbicides, applied in near shore areas of a large, shallow lake, Clear Lake, California, which is the site of a hydrilla eradication program. The study was performed in the embayment off Reeves Point and the Big Valley Rancheria, where hydrilla was first discovered in Clear Lake.

Currents were inferred from water temperatures measured with high accuracy thermistors, at various depths in the water column, and were measured directly using acousitic Doppler velocity profilers. The data indicated that the herbicides applied in the Upper Arm can be transported from the treatment areas by several mechanisms. During summer, the water column was stratified for a few days before a complete mixing event. In cooler seasons, the water column was vertically mixed on a diurnal basis. Application of herbicides in the early morning after a nighttime mixing event is thus more likely to reach the targeted plants on the bottom, than when density stratification of the water column in prevalent.

Daytime surface current at the outer embayment was typically 5 – 10cm/s with an eastward or westward direction depending on the basin scale waves. Bottom current was about 1 – 5 cm/s with a more variable direction. Thus, herbicide in the top of the water column could have been transported by a distance on the order of 500 to 2000 m, whereas close to the bottom by approximately 100 to 400 m. The night pattern was much less regular than the daytime one. Water current at night was typically below 2 – 3 cm/s; often it was below 1 cm/s with a variable direction. Horizontal temperature differences during nighttime cooling had the potential of resulting in velocities on the order of 5 cm/s. Velocity profiles from the Rancheria embayment confirmed such a current during an early summer nighttime cooling. The bottom water at the outer edge of the embayment moved at approximately 2 cm/s constantly away from shore and the top water moved in the opposite direction with the same velocity. Thus, the cooler near shore water slid under the warmer water further off shore and was replaced by the far-shore warmer surface water. During this period, herbicide close to the bottom could have been transported close to 500 m. The longitudinal centerline of the embayment is about 360 m long, which is close to the extent of the treatment area. Therefore, during this event, the entire water of the embayment was potentially transported off shore and replaced with far-shore surface water.

Student Paper

Fall Application of Sonar for Control of *Egeria densa* in a Seasonally-Filled Lake in Northern California

Lars W. J. Anderson, Chris Pirosko, USDA-ARS Exotic and Invasive Weed Research, UC Davis, CA, and Tyler Koshnick, SePRO Corporation, Carmel, IN

Blogett Lake in Sacramento County, CA has rapidly shifted from a system predominantly populated by pondweed (*P. nodosus*) and coontail (*Ceratophyllum demersum*) to one dominated by *E. densa* over the past 5 years. This 35-acre lake receives extensive fall-winter runoff from seasonal rains which raises average depths by 5 to 6 ft. To determine if fall applications of sonar would reduce subsequent spring re-growth, 4 AS was applied to reach 20 ppb and SRP at 30 ppb. In one small arm of the lake (ca. 1.5 acre), copper was applied (10 gal. Nautique) as a contact herbicide. Subsequent water analysis showed that concentrations ranged from 15 to 20 ppb for ca. 80 days, after which the first significant rainfalls occurred. Post-runoff fluridone levels plummeted to less than 5 ppb. Typical fluridone symptoms were present throughout the fall-early winter months. Nautique produced typical copper symptoms (defoliation, loss of stem integrity) within 7 to 10 DAT. Regrowth during spring of 2000 will be assessed and discussed.

Differential Response of Hydrilla to Fluridone

Mike Netherland, SePRO Corp., Carmel, IN, William T. Haller, University of Florida, Center for Aquatic Plants, Gainesville, FL, Carole A. Lembi, Purdue University, West Lafayette, IN, and Kurt D. Getsinger, U. S. Army Engineer Research and Development Center, Vicksburg, MS

Hydrilla (*Hydrilla verticillata* L.f. Royle) is recognized as a highly susceptible species to the herbicide Sonar (a.i. fluridone). Recent laboratory, mesocosm, and biochemical evaluations of hydrilla populations collected from various water bodies in Central Florida, suggest that differential sensitivity to fluridone exists between several of the lakes that were sampled. While some populations exhibit threshold responses to fluridone concentrations as low as 2 ppb, other populations do not exhibit a similar response until concentrations are elevated as high as 10 to 20 ppb. This phenomenon, although known to lake managers, has not been previously documented, and it is suspected that previous treatments with fluridone are a contributing factor in the increased tolerance of these populations. Nevertheless, a prior history of treatment was not a consistent indicator of decreased hydrilla susceptibility to fluridone. A laboratory assay has been developed to detect plant sensitivity and this assay has recently been proven to be an excellent tool for predicting the level of fluridone required to achieve a threshold response. Plant biochemical monitoring in conjunction with FasTEST values has also proven valuable in determining the status of hydrilla to fluridone treatments. The implications of differential hydrilla senstivity to fluridone in Central Florida will be addressed as well as suggested areas of new research.

NOTES

SESSION VI

Restoration of a Shallow Lake Through Drawdown

John D. Madsen, R. Michael Stewart, and John W. Barko, U. S. Army Engineer Research and Development Center, Vicksburg, MS , Daniel R. Helsel', Wisconsin Department of Natural Resources, Madison, WI

Big Muskego Lake is a large shallow lake located in southeastern Wisconsin. The lake suffered high turbidity and low plant populations as a result of excessive carp populations, historical waste water discharges and high internal loading. In 1996, a restoration project was initiated that included an extensive year-long drawdown, fish eradication, vegetation management and watershed best management practices. The restoration project was successful in shifting the lake from a turbid, algae-dominated phase to a clear-water, aquatic plant-dominated phase. The distribution and biomass of aquatic plants were monitored pre- and post-drawdown. In 1995 (before drawdown), a total of 19 species, including 4 emergent species, 2 floating-leaved species and 13 submerged species, were documented in the lake. Prior to the restoration, Big Muskego Lake was dominated by Eurasian watermilfoil (90% of lake). The mean diversity (n=214) was 1.45 species/sample point, but the number of mean native species at each sample point was only 0.43 species/sample point. Following drawdown, Eurasian watermilfoil was still common, but found at less than 40% of the sample points (n=209). The dominant submerged plant was *Chara*, found at 67% of the sample points. The number of species increased from 19 to 25 including 17 submerged species, 5 floating-leaved species, and 3 emergent species. Mean diversity increased from 1.45 species/sample point to 4.4 species/sample with an average of 3.8 native species/sample point. Transparency increased at least 3-fold. In this instance, restoration efforts were successful in converting a turbid lake dominated by a nonnative species to a clear lake dominated by desirable native submersed and emergent species.

Potential Control of *Hydrilla verticillata* by Use of a Classical Biocontrol Agent in Combination with a Competitive Native Plant Species (WU 33117)

Michael J. Grodowitz and R. Michael Smart, U. S. Army Engineer Research and Development Center, Vicksburg, MS, Robert Doyle' University of North Texas, Denton, TX .

Hydrilla is an aggressive aquatic weed native to Asia that is currently causing enormous management and ecological problems in North America. The possibility of managing *Hydrilla verticillata* (hydrilla) with the combination of a classic biocontrol agent (*Hydrellia pakistanae*) and a new plant competition technique was investigated in this two-year tank study. For this experiment, hydrilla was planted in sixteen 14,000 liter tanks either alone or in the presence of *Vallisneria americana*, a competitive, non-nuisance aquatic plant. Half of these tanks were then inoculated with *H. pakistanae* larvae. *Hydrellia pakistanae* populations were monitored and amended as needed to maintain a viable biocontrol population within these tanks. After two growing seasons, the tanks were harvested for plant biomass, tuber numbers, insect numbers, and associated leaf damage. In the absence of *H. pakistanae* (the biocontrol agent) or vallisneria (the competing plant species) hydrilla grew luxuriantly and quickly expanded into neighboring, unplanted pots within the tanks. In the presence of vallisneria, total hydrilla mass was reduced by 38% and the expansion of the original plants into neighboring pots was minimal with an expansion suppression of 61%. In the presence of *H. pakistanae*, the hydrilla plants were noticeably damaged and total biomass in the tanks was reduced by 37%. In addition, expansion into neighboring pots was reduced (38%) but to a lesser extent than in the presence of vallisneria. Tuber number was also reduced significantly in treatments containing vallisneria (53%) or *H. pakistanae* (26%). *Hydrellia pakistanae* damage was shown to decrease the photosynthetic potential of affected hydrilla stems by approximately 50%, which may partially explain the reductions in biomass and expansion into unplanted neighboring pots observed in the large-scale tank studies.

Nutritional Status of *Hydrilla verticillata* Grown Under Various Environmental Conditions, and Its Effect on *Hydrellia pakistanae* (WU 33305 & 33028)

Jan E. Freedman, Michael J. Grodowitz, and Dwilette G. McFarland, U. S. Army Engineer Research and Development Center, Vicksburg, MS

Techniques were developed that allowed the production of *Hydrilla verticillata* plants of known nutritional compositions with relatively minor differences in leaf physical characteristics. This was accomplished by varying levels of nitrogen in the sediment, increasing the gaseous CO_2 concentration in the water, and increasing the length of time the plants were allowed to grow. One of the major nutritional factors altered was plant tissue nitrogen concentration. *Hydrellia pakistanae* larvae exposed to leaf tissues of different nutritional compositions produced adults that exhibited differences in the number of eggs oviposited/female, number of days to first adult emergence, and percent emergence. Females reared on plants grown in high sediment nitrogen conditions produced > 2-fold more eggs/female and had a significantly shorter time to first adult emergence (ca. 2 days). Similarly, mean percentage emergence was dependent on fertilization level and CO_2 concentration with > 10 % higher emergence in treatments with high fertilization and increased CO_2 concentrations. Based on these experiments changes in plant nutritional composition at field locations could drastically influence establishment success and population increase of *H. pakistanae*.

Impact of Parasites and Predators on *Hydrellia pakistanae*, a Biological Control Agent of *Hydrilla verticillata* (WU 33028)

Christi Snell and Jennifer Booker, University of North Texas, Denton, TX, Michael J. Grodowitz and Alfred F. Cofrancesco, U. S. Army Engineer Research and Development Center, Vicksburg, MS

Studies initiated during 1999, were designed to examine the influence parasites and predators have on *H. pakistanae* emergence and population size. Field parasitism rates of *H. pakistanae* by the hymenopteran parasite *Trichopria columbiana* were quantified. Parasitism rates varied tremendously ranging from 0% to > 80% of all fly plus parasite emergence with higher rates associated with *H. pakistanae* pupae collected later in the year; i.e., after September. Gut contents of commonly encountered dragonfly and damselfly (Odonata) immatures were also examined to determine if *H. pakistanae* larvae were a primary food component. No evidence of Odonata feeding on *H. pakistanae* larvae was observed from field collected immatures, even when population levels of *H. pakistanae* were high. While predation by odonates seems minimal, high levels of parasitism by *T. columbiana* could possibly hinder the development of damaging population levels of *H. pakistanae* at field locations.

Student Paper

Possible Impact of *Hydrellia pakistanae* on Lake Seminole Hydrilla (WU 33028)

Alfred F. Cofrancesco. Michael J. Grodowitz, R. Michael Stewart, and John D. Madsen, U. S. Army Engineer Research and Development Center, Vicksburg, MS, Don Morgan, U. S. Army Engineer District, Mobile, Lake Seminole Field Office, Chattahoochee, FL, and Ed Snoddy, Formerly with Tennessee Valley Authority, Muscle Shoals, AL

Hydrilla verticillata has been a continuing problem on Lake Seminole since the early 1980's. Beginning in 1990 and continuing through 1992, over 2,000,000 *Hydrellia pakistanae*, a leaf-mining fly of hydrilla, were released for management purposes. Limited quantitative surveys on the lake during the early establishment period revealed the presence of a low but persistent population of *H. pakistanae*. During the 1996 surveys and continuing through 1998, qualitative observations indicated distinct changes in the hydrilla status where formerly monotypic infestations were being replaced with a more diverse assemblage of plants. In August and September 1999, very large populations of *H. pakistanae* adults were observed in several areas. Hydrilla in these locations was heavily damaged and numerous broken stems were observed floating on the water surface. Quantitative samples during September 1999 revealed leaf damage of about 16 % and peak immature numbers of over 2,500 immatures/kg wet plant material. Biomass and tuber samples taken during November 1999 revealed that while no significant differences in biomass could be detected, significantly lower tuber densities were associated with locations with past histories of high insect damage during the earlier portion of 1999. Tuber densities in these sites more heavily impacted by insect damage were reduced about 60%. In addition, numbers of plant species in impacted areas were about 2-fold higher. The changes in plant diversity observed on the lake over the last several years could possible be associated with lower tuber densities.

Population Management of Triploid Grass Carp (WU 33200)

James P. Kirk, U. S. Army Engineer Research and Development Center, Vicksburg, MS

This work is comprised of three elements designed to enhance the utility of triploid grass carp as a management tool to control aquatic vegetation in large water bodies. The elements included population assessment and modeling in the Santee Cooper reservoirs of South Carolina, biotelemetry studies in a coastal river to study emigration potential into estuarine areas, and an evaluation of the feasibility of injectable pellets as a method to limit life span. A series of population assessments were made because triploid grass carp decreased hydrilla coverage in the Santee Cooper reservoirs from a high of 17,000 hectares in 1994 to remnant stands by 1997. During 1999, annual mortality increased significantly and we estimated approximately 63,000 triploid grass carp remaining out of 768,500 stocked between 1989 through 1996. Future management objectives will allow submersed vegetation to increase to an intermediate level by matching density of fish to a desired level of submersed vegetation. Twenty tripoid grass carp (> 85 cm total length) were tagged with sonic and radio transmitters and released into the Cooper River to determine their potential of emigration into estuarine reaches of the river. To date, individuals remained near hydrilla stands in the river and adjacent rice fields. Winter and early spring tracking will ascertain if fish move in response to spawning cues or in search of food. The feasibility of injectable pellets, containing rotenone, that limit life span will be evaluated next year. The major task is to find a suitable polymer coating that is available, effective, and affordable.

Macrophyte Management via Mechanical Shredding: Effects on Water Quality in Lake Champlain (Vermont-New York)

William F. James and Harry L. Eakin, U. S. Army Engineer Research and Development Center, Spring Valley, WI, and John W. Barko, U. S. Army Engineer Research and Development Center, Vicksburg, MS

We examined the impacts of mechanical shredding (i.e., shredding plants and leaving biomass in the system) of the water chestnut (*Trapa natans*) on water quality and nutrient mobilization at a control and experimental site in Lake Champlain (Vermont-New York). A 100 ha plot was mechanically shredded (Penny system) on 26 July, 1999. Broken plant material was initially concentrated on the lake surface of the experimental station after shredding, but began settling after ~ 7 days. Over a two week period after shredding, concentrations of total nitrogen (N) and phosphorus (P), and soluble reactive P increased in the lower water column of the experimental station, coinciding with decomposition of *T. natans*. Sediments in the control and experimental stations exhibited very low rates of N and P release under oxic and anoxic conditions and could not account for increases in nutrient concentrations in the water column after mechanical shredding. Shredded plant material deployed in mesh bags at the experimental station lost ~ 70% of their total mass, and 42% N and 70% P within 14 days, indicating substantial nutrient mobilization via autolysis and decomposition. Chlorophyll a concentrations increased to 35 g/L at the experimental station on day 7 after shredding, compared to a concentration of 4 g/L at the control station, suggesting uptake of mobilized nutrients for phytoplankton growth. Disruption of the surface canopy of *T. natans* by shredding was associated with marked increases in turbidity and dissolved oxygen, suggesting increased mixing at the experimental station. These effects on water quality need to be considered in the development of management plans for controlling *T. natans* via mechanical shredding.

NOTES

SESSION VII

Commercial Use of the Milfoil Weevil *Eurhychiopsis lecontei* as a Biological Control for Eurasian Watermilfoil

Martin Hilovsky and Christina Brant, EnviroScience, Inc., Stow, OH, Sallie Sheldon, Middlebury College, Middlebury, VT

Eurasian watermilfoil (EWM), an exotic aquatic plant introduced into North America in the 1940's, has spread rapidly throughout the United States and Canada, inhibiting recreational activities and out-competing native plants in lakes and reservoirs. *Eurhychiopsis lecontei*, an aquatic weevil investigated by one of us (Sheldon) over the past decade, has shown considerable potential as a biological control for EWM. In 1998, EnviroScience, Inc., Stow, OH, in agreement with Middlebury College, began commercially marketing the weevil within the context of the MiddFoil® Program. The program includes an initial assessment of the lake, stocking of the milfoil weevils, and continued monitoring of the weevil population and its effects on the plant community. Twenty four lakes in eight states were stocked by EnviroScience, Inc. in 1998 and 1999. Data collection methods, used to assess the stocking, will be reviewed. Case studies of several successful stockings, and at least one unsuccessful stocking, will be presented. Overall results are very positive, indicating growing weevil populations and increased weevil damage to EWM plants in lakes of varying size and water quality.

Overwinter Habitat and the Relationship of Overwinter to In-lake Densities of the Milfoil Weevil, *Euhrychiopsis lecontei*, a Eurasian Watermilfoil Biological Control Agent

Raymond M. Newman, David W. Ragsdale, Alyson Milles, and Cary Oien, University of Minnesota, Fisheries and Wildlife, St. Paul, MN

The native weevil *Euhrychiopsis lecontei* has been associated with experimental and natural declines of Eurasian watermilfoil (*Myriophyllum spicatum*). The weevil spends the summer submersed, completing development (egg, larva, pupa and adult) on watermilfoil plants, producing 3 to 6 generations in a summer. Submersed weevils have poorly developed flight muscles, apparently allocating energy to reproduction. In the fall adult weevils move to shore where they overwinter in leaf litter (top 5cm of soil) at dry sites near the shoreline. Mean November shoreline densities at Lake Auburn and Smith's Bay of Lake Minnetonka, from 1992-1998, have ranged from zero to over 200/m^2. Overwinter mortality is not severe; spring shoreline densities ranged from zero to 340/m^2 and mortality from fall to spring was generally < 50%. Overwintering adults have developed flight muscle and limited flight has been observed in the spring. Adults return to the water between ice-out and mid-May, when reproduction begins. Spring (May-June) and September in-lake densities in these two lakes have ranged from zero to 40/m^2 and Lake Auburn typically had higher in-lake weevil densities (mean of 15/m^2 compared to 4/m^2 at Smith's Bay). There was no relationship between in-lake and shoreline densities at Lake Auburn, but Smith's Bay spring in-lake densities were correlated with spring shoreline densities. In-lake densities were not correlated between the two lakes but shoreline densities were correlated over time, suggesting that regional climatic factors may influence shoreline densities. Weevils disappeared from in-lake samples in Lake Auburn in July 1998 and no weevils were found in shoreline or in-lake samples in 1999. In-lake factors such as fish predation may be more important limiting factors than overwinter habitat

Indigenous populations of Euhrychiopsis, Acentria, and Cricotopus with Implications for the Biological Control of Eurasian Watermilfoil

Robert L. Johnson, Cornell University, Ithaca, NY

Naturally occurring populations of three invertebrate herbivores, the weevil *Euhrychiopsis lecontei*, the moth *Acentria ephemerella,* and the midge *Cricotopus myriophylli* feed on Eurasian watermilfoil in New York Lakes. We record populations of these three herbivores at high densities in several lakes throughout New York State. Mean individuals per 25 cm apical meristem of Eurasian watermilfoil often surpasses one *E. lecontei* or *A. ephemerella,* with densities greater that one *C. myriophylli* per apical meristem occasionally found in our samplings. Along with these large populations of watermilfoil herbivores, we record extensive damage to the apical meristem of Eurasian watermilfoil. Consideration of indigenous population numbers and their life cycle is important to determine the potential for biological control of Eurasian watermilfoil by these three invertebrates. We examine recorded population densities of, and augmentations to, native populations of Eurasian watermilfoil herbivores. These observations suggest that if there is an inference of efficacy an estimate of current herbivore populations in a lake is essential before attempting biological control with augmentation of one of these herbivores to the present invertebrate inhabitants. This population estimate requires adequate sampling to allow statistical analysis.

The Search for Exudates from Eurasian Watermilfoil and Hydrilla

Lee Ann Glomski, Carole A. Lembi, Karl V. Wood, Ralph L. Nicholson, and Phillip Wharton, Purdue University, W. Lafayette, IN

Plants are well known for their ability to produce secondary metabolites, compounds that benefit the plant by inhibiting the growth of potential disease organisms, herbivores or competitors. Some secondary metabolites have also been shown to be toxic and/or carcinogenic to animals. Secondary metabolites are also produced by aquatic plants, and in some instances, exudation of these metabolites into the surrounding water has been detected. To determine whether infestations of Eurasian watermilfoil or hydrilla produce such exudates, plant tissues and water samples were collected from laboratory cultures, stock tank cultures, and pond populations. These samples were analyzed using solid phase extraction, HPLC, thin layer chromatography, and various methods of mass spectrometry including electrospray ionization, GC/MS, EI (electron impact), CI (chemical ionization), PDMS, and MALDI. Previously-reported compounds such as tellimagrandin (Eurasian watermilfoil) and a caffeic acid ester (hydrilla), along with a newly discovered flavonoid, cyanidin 3-dimalonylglucoside (hydrilla), were readily detected in plant tissues but were not detected in any of the water samples. The only exception was a compound that appeared both in Eurasian watermilfoil samples treated with a herbicide and in pond samples collected during Eurasian watermilfoil senescence. This compound is currently being identified. If compounds are being released, as suggested by researchers using axenic cultures, they may be rapidly broken down by bacteria so that they are not readily detectable in water.

Student Paper

Selected Fungal Associates of *Myriophyllum spicatum* L.: Pathogens or Endophytes? (WU 33306)

Judy F. Shearer, U. S. Army Engineer Research and Development Center, Vicksburg, MS

Over the past several years plant samples collected from populations of *Myriophyllum spicatum* L. (milfoil) both in the United States and overseas have been assayed for potential biological control pathogens. The tissue samples have come not only from milfoil populations that appeared diseased and in various states of decline but also from populations that appeared vigorous and healthy. The range of fungal organisms isolated from *M. spicatum* is extensive yielding to date a compilation of over 100 species. Two genera, *Mycoleptodiscus* and *Acremonium*, consistently appear on species isolation lists regardless of the vigor of the milfoil population. Members of both genera have demonstrated pathogenicity against *M. spicatum* in greenhouse trials and have been suggested as potential innundative biocontrol agents. Their regular isolation from field populations of milfoil suggests their presence in tissues may primarily be as endophytes and secondarily as weak pathogens. Conditions that weaken populations of the host may induce species of *Mycoleptodiscus* and *Acremonium* to change from an endophytic to a pathogenic state.

Epiphytic Macroinvertebrate Abundance Along a Gradient of Eurasian WaterMilfoil Cover

K. S. Cheruvelil, P. A. Soranno, and M. J. Sanborn, Michigan State University, East Lansing, MI, East Langsing, MI, J. D. Madsen, U. S. Army Engineer Research and Development Center, Vicksburg, MS

The exotic macrophyte Eurasian watermilfoil (*Myriophyllum spicatum L.*) has spread widely throughout North American and has come to dominate macrophyte communities in many North temperate lakes. Because of the central role that macrophytes play in many fish-macroinvertebrate interactions, the spread of this nuisance species, and subsequent plant management actions, could potentially alter many lake foodweb interactions. In particular, the dense canopies Eurasian watermilfoil forms and its morphology may influence the colonization of epiphytic macroinvertebrates. In this study, we examined how changes in Eurasian watermilfoil cover affect epiphytic macroinvertebrate abundance. Our research questions were: 1) Does macroinvertebrate abundance vary predictably along a gradient of Eurasian watermilfoil cover? And, 2) If so, is this result a function of a predictable relationship between macroinvertebrate abundance and plant species and/or plant morphology? To answer these questions, we sample 15 macrophyte species from 6 southern Michigan lakes in August 1999. Eurasian watermilfoil cover in the vegetated littoral zone of the lakes ranged from 21-95%. Lakes low on the gradient were sampled as part of a study examining the direct and indirect effects of whole-lake herbicide treatments (Sonar® application May 1997) on plants, fish, and invertebrates. 'Reference' lakes were chosen that had high percent Eurasian watermilfoil cover and undergo little plant management. Results suggest that as percent Eurasian watermilfoil cover increases, macroinvertebrate abundance decreases. However, we also found that in general, macroinvertebrate abundance is greater on plants with increased leaf dissection.

Student Paper

The Indirect Effects of Eurasian Watermilfoil, and Its Management, on Largemouth Bass Recruitment

Rahman D. Valley and Marty T. Bremigan, Michigan State University, East Lansing, MI

Harmful effects of invasive, canopy forming macrophytes such as Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) on native plant populations and lake aesthetics have been well demonstrated. Although great efforts are put forth to control EWM, effects of its management on sportfish production are insufficiently understood. Macrophytes can affect foraging success and growth of largemouth bass (*Micropterus salmoides*; LMB). Therefore, changes in macrophyte abundance or structure caused by invasion and/or subsequent removal of exotic macrophytes may affect age-0 LMB growth and recruitment. We hypothesize that: (1) EWM negatively affects age-0 LMB growth and recruitment by homogenization of macrophyte structure, and (2) control of EWM that promotes native macrophytes benefits age-0 LMB growth and recruitment. In a small-scale age-0 LMB foraging behavior experiment, EWM monocultures, dense plants, and low bluegill (*Lepomis macrochirus*; BG) prey abundance significantly reduced LMB foraging success. In a multi-lake (5 lakes, 2 years) evaluation of the indirect effects of herbicide control of EWM on age-0 LMB, percent coverage of EWM ranged 8%-92%. Production of age-0 BG prey, which did not vary predictably with EWM coverage, positively correlated with age-0 LMB growth ($p=0.11$). Eurasian watermilfoil coverage could not explain variation in these residuals ($p=0.55$), perhaps due to heterogeneous macrophyte structure in all lakes. Diet analysis and bioenergetic modeling confirmed the importance of BG prey for age-0 LMB growth. Overall, our data indicate that herbicide control of EWM will not negatively affect age-0LMB, and may enhance growth, provided high production of bluegill prey and native macrophyte persistence.

Washington's Aquatic Plant Quarantine - Preventing the Introduction of the Next Eurasian Watermilfoil.

Kathy Hamel and Jennifer Parsons, Washington Department of Ecology, Olympia, WA

Washington is home to a number of nonindigenous aquatic problem plants like Eurasian watermilfoil, Brazilian elodea, and parrotfeather. All are suspected to have been introduced via the aquarium and nursery industry. The popularity of the Internet provides yet another opportunity for people to trade or acquire invasive non-native plants. As part Washington's overall statewide strategy to close introduction pathways for aquatic nonindigenous species, the Washington Department of Agriculture is proposing to prohibit the sale and transport of selected aquatic plant species. Some of the species are already here and others are perceived to be a significant threat to Washington waters should they become established. Hopefully other states in the western region will adopt similar regulatory strategies and we all can protect each other from the introduction of the next milfoil or hydrilla.

Eurasian Watermilfoil Control and Exotic Species Prevention in Seattle's Lake Youngs Reservoir

Rob Zisette, Herrera Environmental Consultants, Seattle, WA

Lake Youngs is a 283-hectare (700-acre) reservoir that provides drinking water to over one million people in the Seattle metropolitan area. Eurasian watermilfoil (Myriophyllum spicatum) was first observed in the reservoir in September 1992. A milfoil control program was initiated in 1993 by installing bottom barrier and hand-pulling plants in the infestation area located adjacent to the boat launch on the east shore of the reservoir. Hand-pulling efforts continued in 1994 and 1995. A new infestation was detected on the west shore in 1996 that was controlled with a bottom barrier. Milfoil plants have not been detected in the reservoir in the past three years, indicating that the milfoil control program has achieved its goal of eradication without the use of herbicides. A program was also developed for preventing infestations of exotic plant and animal species in Seattle's drinking water reservoirs.

Evaluation of Sonar versus Egeria and Eurasian Watermilfoil in a Flowing Environment

Michael D. Netherland and Steve D. Cockreham, SePRO Corporation, Carmel, IN, John G. Skogerboe, U. S. Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

Egeria (***Egeria densa*** Planch) and Eurasian watermilfoil (*Myriophyllum* ***spicatum*** L.) were established in a series of 6700 L flow-through mesocosms located at the Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX. Sonar (active ingredient fluridone) was applied to the mesocosms on May 14, 1999 and a flow-through system was activated to simulate both a 36- and 72-hr water exchange half-life. Both plant species were actively growing and robust prior to treatment. Sonar treatments for which residues were maintained between 1 and 3 ppb resulted in near 100% control of Eurasian watermilfoil, while egeria biomass was not different from untreated controls by 8 WAT. Treatments resulting in Sonar residues being maintained between 3 and 6 ppb completely controlled the Eurasian watermilfoil, while Egeria biomass was reduced by >65% compared to untreated controls. It was noted that visual symptoms on the egeria were generally lacking; however, despite the lack of symptoms the growth potential of egeria was greatly reduced at these concentrations. Treatments that yielded peak concentrations above 7 ppb provided 100% control of Eurasian watermilfoil and > 90% egeria biomass reduction by 8 WAT. The increased Sonar residues resulted in the typical bleaching symptoms on the growing apical meristems of egeria. Results confirm earlier mesocosm work that showed Eurasian watermilfoil to be highly sensitive to Sonar at low concentrations. Moreover, these results suggest that a higher threshold concentration of Sonar will be required to provide control of egeria. Challenges associated with Sonar use in flowing waterbodies will require that water residues be closely monitored to insure that threshold rates are maintained for the target species.

Low Dose Applications of Triclopyr for the Selective Control of Eurasian Watermilfoil (WU 32841)

Angela G. Poovey, AScI Corporation, U.S. Army Engineer Research and Development Center, Vicksburg, MS, John G. Skogerboe, U. S. Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX, Kurt D. Getsinger, John D. Madsen, R. Michael Stewart, U. S. Army Engineer Research and Development Center, Vicksburg, MS, Tyler Koschnick, and Alicia Staddon, SePRO Corp., and David R. Honnell, University of North Texas, Denton, TX

Spot treatments of triclopyr were conducted on Lakes Minnetonka and Minnewashta during June 1998 to investigate its potential to selectively control milfoil (*Myriophyllum spicatum* L.) at low doses. One hectare (2.5 acres) plots were dosed with triclopyr TEA, as Renovate®, at rates of 0.5, 1.0 and 1.5 mg L^{-1} active ingredient. Untreated plots served as references. Water samples, collected to monitor herbicide dissipation, were analyzed with both HPLC and an immuno-assay technique (FasTEST). Results from these two methods were compared and found to be statistically similar ($p=0.05$). Triclopyr had a relatively short half-life for each treatment (3.5 h at 0.5 mg L^{-1}, 2.9 h at 1.0 mg L^{-1}, and 4.2 h at 1.5 mg L^{-1}). Wind and temperature conditions during and after application may have increased water exchange inside the plots augmenting herbicide dispersion. Frequency of milfoil decreased by 30% at 0.5 mg L^{-1}, 35% at 1.0 mg L^{-1}, and 45% at 1.5 mg L^{-1}; plants that survived treatment were small and damaged. Decline in frequency of native plants after application could be partially attributed to the natural onset of senescence as distribution was significantly greater pre-application for the reference and at 0.5 mg L^{-1} ($p=0.001$). This decline was also statistically significant for the 1.0 and 1.5 mg L^{-1} treatments ($p=0.035$ and $p=0.045$, respectively) where milfoil control was greatest. However, native plant diversity did not change at 1.0 and 1.5 mg L^{-1} but decreased for the reference and at 0.5 mg L^{-1}. Larger treatment areas may enhance triclopyr efficacy; however, treatments of small areas can be effective in encouraging native species to expand by reducing milfoil distribution during the growing season.

Responses of Eurasian Watermilfoil (*Myriophyllum spicatum*) to Three Endothall Products (Aquathol K, Hydrothol 191, Super K)

Lars W. J. Anderson and Chris Pirosko, USDA-ARS Exotic and Invasive Weed Research, Weed Science Program, Davis, CA

Eurasian watermilfoil continues to impact Western aquatic sites such as irrigation systems, small ponds, reservoirs, and the pristine high mountain Lake Tahoe and its only outlet, the Truckee River. The efficacy of three endothall formulations on *M. spicatum* (transplanted from Lake Tahoe) was compared to assess the utility of organic contact herbicide s with short half-lives. All formulations depressed biomass, shoot production and shoot elongation at concentrations of 0.5; 1.5, and 3.0 ppm with 24 h exposures. Super K and Aquathol K at 1.5 ppm reduced biomass by ca. 98% 42 DAT; whereas, Hydrothol 191 reduced biomass by ca. 80-85%. Plant height and numbers of new lateral shoots were significantly suppressed in all exposures. Compared to untreated plants, all formulations at 0.5 ppm resulted in lower proportion of long laterals (i.e., >40 cm) 42 DAT, though significant biomass remained intact. These data suggest that endothall may be useful in managing *M. spicatum* in circumstances where exposure-time is limited and rapid herbicide dissipation is desirable, and where water quality and other environmental constraints preclude the use of either copper-containing products or systemic products that require several weeks' exposure.

SESSION VIII

Comparison of Three Sampling Techniques for Quantifying Submersed Aquatic Plants in L'Anse Creuse Bay, Lake St. Clair (WU 33127)

R. Michael Stewart, John D. Madsen, and Bruce M. Sabol, U. S. Army Engineer Research and Development Center, Vicksburg, MS

Submersed aquatic plants in a portion (ca. 10-km^2) of the L'Anse Creuse Bay region of Lake St. Clair, Michigan, were surveyed with three techniques during 1998. The primary objective of the survey was to determine the distribution and frequency of occurrence of submersed aquatic plants within the study area. Survey techniques utilized were: (a) point-intercept sampling, (b) transect sampling, and (c) aerial photography. Point-intercept sampling was conducted on 18-19 August at 165 points chosen from a stratified-random design based on a 200-m X 200-m grid overlay of the study area. Geographical coordinates for the points were determined by MapInfo software, a GIS-type mapping package. At each point, submersed plant species collected by a vertical rake toss were recorded, as was water depth. Transect sampling was conducted using the ERDC developed Submersed Aquatic Vegetation Early Warning System (SAVEWS). For specified intervals along the transect, SAVEWS provided an estimate of (a) average water depth, (b) frequency of occurrence of submersed vegetation, and (c) average plant height (for vegetated areas only). Coordinates for the starting and ending points for 22 transects were selected from the point-intercept sampling points. Transects were surveyed on 19-20 August, and ranged in length from 0.6 to 1.8-km. True-color aerial photographs of the study area were shot on 28 August, between 1100 and 1300 hours. The mission included eight flight lines and a total of 85 photos, which were printed at a scale of 1:6000 (1"=500'). Photo-interpretation consisted of delineating areas based on vegetation density classifications (e.g., non-vegetated, moderately vegetated, or heavily vegetated). Resulting data sets are summarized and compared to provide a basis for evaluating the strengths and weaknesses of the three methods.

Remote Sensing and Bathymetric Mapping Techniques to Support Large-Scale Sonar Applications

Doug Henderson and Terry McNabb, ReMetrix LLC, Carmel, IN

Sonar has been proven an effective tool for managing large-scale infestations of nuisance exotics such as hydrilla (Hydrilla verticillata L.f. Royle). Treatment strategies and use of the FasTEST immunoassay have evolved over the past several years to allow managers to maintain low threshold concentrations of Sonar to provide target plant control. In large systems, a critical component to prescribing Sonar treatments at the part per billion level is an accurate calculation of water volume. To provide this valuable information for the Kissimmee Chain of Lakes in Central Florida (62,000 surface acres), ReMetrix used technologies that combine space-based sensors to image the lakes and DGPS equipped bathymetric mapping vessels. Image scenes were collected in January 2000 providing coverage of the lakes, and field crews traversed the lakes in the mapping vessel collecting submeter GPS points linked to depth attributes. Image processing and mapping techniques were used to develop highly accurate water volume information. Moreover, this work provides an excellent pretreatment inventory of hydrilla and other vegetation prior to Sonar application. This information will be used to target priority treatment zones as well as to assess treatment impacts in the late summer. This initial collection of data will also allow for monitoring long-term changes in the vegetation. As public and regulatory agencies increasingly request more information prior to deciding on management alternatives, improved data collection capabilities and integration of this data with knowledge of aquatic herbicides and plant biology will continue to improve the science of aquatic plant management.

What's Out There for GPS Data Collection?

Patrick Akers, California Dept. of Agriculture

A GPS receiver provides a rapid method to mark a position with very good, though not perfect, accuracy. With Selective Availability now turned off, the inherent accuracy of the GPS system is roughly 17 to 20 meters (radius of 95% confidence interval), plus the accuracy of the GPS receiver itself. The accuracy was 100 meters when Selective Availability was turned on. With differential correction, the accuracy may easily be improved to less than a meter, plus the accuracy of the GPS receiver itself. Accuracy of receivers (with one second of data) ranges from less than 0.5 meters for high-end mapping units to 5-7 meters for modest recreational units. In considering the options for a GPS data collection system, cost must be weighed against using differential correction for higher accuracy for mapping purposes, against the time needed for gathering positional information, the accuracy of the GPS receiver itself, data entry capabilities, convenience of use, and accurate navigation. There are a wide range of options, each providing different capabilities and costs.

The first step is to establish priorities, including accuracy requirements and cost. Careful field marking of 7.5-min USGS topographic quads can probably provide results that are somewhat better, on average, than uncorrected GPS. The markings on the maps can also be digitized into a GIS. Improving GPS accuracy to better than 5-7 meters require differential corrections (DGPS), but this adds cost, as does flexible entry of descriptive data and convenient interfacing with GIS programs. The theater of operations can also affect the availability and cost of options. If working within range of the Coast Guard Beacons, a Beacon real-time DGPS receiver is definitely an option to consider carefully. A better sportsman GPS model, with an added consumer-level Beacon receiver, could be accurate to 3-8 meters, within 80 miles of the Beacons, for not much more than $600-700 total. In addition, since the corrections are made in real-time, the unit would be suitable for relatively accurate navigation. Another $1100-1500 could add flexible data entry, by interfacing a Beacon-based real-time DGPS sensor with a consumer handheld computer and appropriate software. If working beyond the range of the Beacons, Trimble's GeoExplorer (or Corvallis Microtechnology's March II) provides some data entry flexibility, good accuracy for mapping via post-processed differential GPS, and no continuing subscription costs for differential correction services once the initial $3000-4500 investment is made. If you can afford an additional $800 per year above the cost of a GeoExplorer, then a handheld computer system interfaced with a satellite-based real-time DGPS will give you accurate map data and navigation, more convenient data entry, and the freedom of satellite RTDGPS. If you can afford $9000-12,000 per unit, high-end mapping systems such as Trimble's ProXRS will provide <0.5 meter accuracy in real-time, and a high degree of flexibility and convenience in data entry and choice of differential correction service.

It's also good to remember that GPS is an emerging technology. It's not changing quite as fast as the computer industry, but each year performance improves, costs drop, and new options appear. If you can't afford what you want now, in a year or two it might be available.

Demonstration of GPS Data Collection: Techniques and Issues (Based on Trimble GeoExplorer GPS Units)

Patrick Akers, California Dept. of Agriculture

Usually the first issue in starting a GPS data collection system is choosing the GPS receiver, where costs must be balanced against accuracy and ease of data entry. This demonstration avoids that problem and focuses on the capabilities of Trimble mapping-grade GPS products, particularly the GeoExplorer. The GeoExplorer strikes a compromise between cost and capabilities that has made it the choice of many. It will serve as a model of the issues that confront most systems.

In collecting GPS data to produce maps, the major issues are: 1) configuring the receiver to collect data of a known accuracy; 2) accessing GPS satellites under field conditions; 3) customizing data entry screens, including limitations in data entry; 4) processing the collected data to obtain higher accuracy if needed (2-3 meters with a GeoExplorer); 5) moving the data from the GPS software into a GIS, including the avoidance of reference system conflicts between the GPS data and the background maps against which it will be displayed; and 6) managing the flow of data and data files. Managing these issues requires working not only with the GeoExplorer GPS receiver itself, but with the PC software, called Pathfinder Office, that permits the programming of the receiver and the preparation of the results.

The demonstration will briefly introduce how the GPS system works in general. Then will come an overview of the menu structure of the GeoExplorer and how to use Pathfinder Office to set up data entry screens, perform the data processing to obtain higher accuracy, export the data and import it into a GIS program (MapInfo). The various issues and pitfalls will be emphasized.

If there is a need to use the GPS unit to navigate with high accuracy (3 meters or less), then the issue arises of obtaining high accuracy in real-time. This capability increases the cost and complexity of the GPS solution and will not be covered here.

NOTES

Alternate Submitted Papers

Evaluation of Sonar for Selective Eurasian watermilfoil Control Within the Treatment Season and at One Year Posttreatment

Tyler J. Koschnick, SePRO Corporation, Carmel, IN, John D. Madsen, U. S. Army Engineer Research and Development Center, Vicksburg, MS, and Chetta Owens, U. S. Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

Sonar was applied to two Michigan Lakes for control of Eurasian watermilfoil (*Myriophyllum spicatum* L.) at an initial rate of 6 µg/L in May 1998. Water was monitored using the FasTEST immunoassay. Results showed that target concentrations were achieved and data were used to calculate the amount of additional product needed to maintain threshold concentrations. Plant communities on two treated and untreated lakes were assessed in May and August of 1998 and 1999. Vegetation sampling was performed using a point-based frequency of species occurrence to evaluate whole-lake distribution and diversity of the submersed plant community. This technique was implemented using grid locations determined by a GIS, and located on each lake using a GPS mounted on a survey boat. Frequency data in August 1998 suggested that partial milfoil control was achieved with an apparent slight decrease in native plant diversity. Total plant cover decreased from near 100 to approximately 85% in the treated lakes by August 1998. Nonetheless, from a lake management perspective, milfoil growth was greatly reduced compared to the initial density observed in May, and native submersed macrophytes remained abundant in the lake. Plant assessment in May and August of 1999 included a combination of point-based frequency and biomass data to better quantify both target and non-target plant density. Results in 1999 indicated a near complete removal of milfoil on one of the treated lakes that was accompanied by an increase in overall species diversity. The other treated lake also showed an increase in native plant diversity, yet a relatively high frequency of very small milfoil plants remained present. While frequency data alone would suggest a widespread milfoil problem, biomass and frequency data indicated that milfoil represented a very small fraction of the total submersed vegetation. In terms of milfoil management, both treatments successfully provided two full seasons of milfoil control with minimal impact to native plants.

Posters

Preventing the Purple Plague From Taking Over California's Waterways

Carri Benefield , Integrated Pest Control Branch, California Department of Food and Agriculture, Sacramento, CA

The California Department of Food and Agriculture (CDFA) was recently awarded a grant by the CALFED Bay-Delta Program to conduct a purple loosestrife prevention, detection, and control program. Purple loosestrife is a showy ornamental that has escaped home gardens and nurseries and moved extensively throughout the wetlands of the United States causing immense ecological destruction. Loosestrife is listed by the CDFA as a "B" rated noxious weed and as a "species with potential to spread explosively" by the California Exotic Pest Plant Council. Based on historic records, the distribution of purple loosestrife is currently in multiple, mostly small and scattered populations, in the Sacramento-San Joaquin Delta system and nearby hydrological units. However, infestations of purple loosestrife often follow a pattern of establishment, maintenance at low numbers, and then dramatic population increase when conditions are optimal.

Purple loosestrife, which spreads primarily by copious production of seed the size of ground-pepper, threatens to become established and forms dense stands that crowd out native wetland vegetation and associated wildlife, thus threatening the overall biodiversity of aquatic, wetland, and riparian areas. The complex interface between farm land and water in the Bay-Delta estuary also provides rich and varied habitat for wildlife, particularly waterfowl. The displacement of valued flora and fauna and the diminishment of critical fish and wildlife habitats has been well documented throughout the United States.

Primary program objectives will be to conduct: (1) a broad education and training campaign, (2) extensive surveying and mapping, (3) a collaborative assessment meeting of cooperators to develop site specific adaptive management plans, resulting in (4) comprehensive local management, control, and eradication efforts, and (5) monitoring. The geographical focus will be on the Sacramento-San Joaquin Delta watershed where there are a number of threatened and declining species due to a multitude of environmental stressors. The project will be an extensive collaborative effort with: CDFA Integrated Pest Control Branch District Biologists, County Agricultural Commissioners, local Weed Management Areas, CA Department of Boating and Waterways, the CA Department of Fish and Game, U.S. Fish and Wildlife Service, USDA-ARS Resource Conservation Districts, and local watershed groups, amongst others.

Concepts for Modeling Competition Between Submersed Macrophyte Species (WU 33308)

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To predict changes in vegetation as a result of changes in resource availability in shallow freshwater bodies a simulation model is being developed that describes the growth of two submersed plant groups, respectively canopy-forming and non-canopy forming. The two plant groups compete for light, inorganic carbon and nutrients (nitrogen and phosphorus). The potential benefits of clonal behavior, frequently inferred in submersed plants, are currently being explored. The model will include optimization strategies, and integrate current knowledge on the ecophysiology of two representative species. Currently considered are hydrilla, Eurasian watermilfoil, and sago pondweed for canopy-forming plants, and American wildcelery for non-canopy forming plants.

Impact of Different Populations of *Euhrychiopsis lecontei* on Eurasian Watermilfoil (WU 33189)

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This study evaluated the impact of three different populations of *Euhrychiopsis lecontei* on Eurasian watermilfoil. Insect populations were obtained from Vermont, Minnesota, and a private company. Twenty, five-foot columns of Eurasian watermilfoil were allowed to grow for 4 weeks. Four columns were randomly selected at week 5 as a pretreatment control and evaluated for plant height, above ground biomass, below ground biomass, and chemical composition of the plants. The remaining sixteen columns were then divided into four groups of four columns each. One group was kept as a post treatment control. The remaining three groups of four columns each received four mated pairs of weevils for each treatment (Vermont, Minnesota, and a private company).

This study was allowed to continue for four weeks and then evaluated similar to the pretreatment control. A significant difference in plant length was observed between the post-treatment control and all the other treatments, including the pre-treatment control. It appeared that once the insects were introduced the plant length did not increase. Another area where significant differences were noted was in the nitrogen concentration present in the plant tissue. Both the post-treated control and the pre-treated control had significantly higher levels of nitrogen than any of the insect treatments. On average there was 23% higher concentration of nitrogen in the controls than the treatments.

Mass-Rearing *Hydrellia pakistanae* Deonier and *Hydrellia balciunasi* Bock, Biological Control Agents of *Hydrilla verticillata* (L.F.) Royle (WU 33028)

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Two insect biocontrol agents of *Hydrilla verticillata*, *Hydrellia pakistanae* Deonier, from southern India, Pakistan, and northern China, and *H. balciunasi* Bock, from Australia, were reared at the U.S. Army Engineer Research and Development Center, Aquatic and Wetlands Research and Development Support Facility, from 1990 until 1993. During this time, 122,549 *H. pakistanae* and 135,906 *H. balciunasi* were produced. Production costs, based on labor and materials, were calculated to be ca. 50 cents per insect. Due to high production costs and the potential of reduced insect quality when reared under laboratory and greenhouse conditions, alternative rearing techniques are being considered. Field collection is one alternative; however, current costs for purchasing field collected *H. pakistanae* from Florida-based dealers is also prohibitively expensive ranging from 40 cents to 60 cents per individual. One method designed to produce large numbers of *Hydrellia* spp. involved the use of small ponds and was tested at the Tennessee Valley Authority Reservation in Muscle Shoals, AL during 1991 to 1993. This method showed promise producing > 2,000,000 *H. pakistanae* in one growing season. The collected individuals were used for releases at Lake Seminole, GA and Lake Boeuf, LA. Currently, new and more economical methods are needed for the large-scale production of *Hydrellia* spp. Two alternative solutions are being considered including the construction of mass rearing facility for greenhouse/laboratory procedures and a series of outdoor ponds at the US Army Engineer Research and Development Center, Vicksburg, MS. These facilities would generate large numbers of high quality insects at substantially reduced production costs due to larger production facilities and the use of minimal labor.

Status of Introduced *Hydrellia* spp. at Alabama, Georgia, and Texas Sites as of November 1999 (WU 33028)

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Hydrellia spp. appears to be expanding in distribution. Fifteen non-release and six release sites were examined in an effort to quantify insect numbers and leaf damage. Forty-seven percent of the non-release sites had at least one species of the introduced *Hydrellia*. Only 20% of the non-release sites had detectable immature levels. Small numbers of adults were hand collected at the remaining sites indicating establishment, albeit at minimal levels.

Population levels of *Hydrellia* spp. immatures at the actual release sites remained at similar levels as observed in 1998 at two sites but was undetectable at the remaining four locations. Decreases at Sheldon Reservoir and Lake Cypress Springs can be accounted for by the disappearance of hydrilla at Sheldon with replacement by other plant species and by removal of hydrilla by grass carp at Lake Cypress Springs.

Nutritional profiles of hydrilla stems and leaves were determined as an initial attempt to explain differences in insect establishment and population increases. Hydrilla leaves contained significantly higher percentages of protein and ash and lower amounts of soluble carbohydrates and crude fiber. While stem nutritional components remained relatively similar, large variations occurred in the leaves for each site. For example, % crude protein varied from a low of 15% at Coleto Creek Reservoir to a high of 28% at Flag Lake. Leaf crude protein exhibited a negative exponential growth curve with numbers of immatures; i.e., higher numbers of immatures were associated with lower protein levels. Similarly, lower leaf hardness was associated with higher number of immatures. While more information is needed, nutritional status of the plants appears to be important in assessing *Hydrellia* spp. population size at field locations.

Surveys of *Eichhornia crassipes* and *Hydrilla verticillata* and Associated Insect Biological Control Agents on the Lower Rio Grande (WU 33028)

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During September 1999, surveys to quantify plant infestations and insect biological control agents of both *Eichhornia crassipes* and *Hydrilla verticillata* were initiated on the Lower Rio Grande from just west of McAllen, TX east to Brownsville, TX. Waterhyacinth biomass differed significantly from site to site and ranged from 3 to about 21 kg/m^2. Both *Neochetina eichhorniae* and *N. bruchi* were commonly collected from all waterhyacinth sites. However, agent numbers were highly variable with an almost four-fold difference in numbers of agents/m^2 observed at the various sites. Strong relationships between various plant parameters and density of insect agents were observed that demonstrate possible insect herbivory impacts. For example, at sites with only 20 *Neochetina* spp./m^2 flower stalks averaged about 14 per m^2. This is contrasted to sites with 80 *Neochetina* spp./ m^2 where flower stalk density was reduced to about 7 per m^2.

Hydrilla populations differed markedly from site to site. While no quantitative measurements were made, visual inspections revealed hydrilla ranging from small, scattered populations to extensive infestations across major portions of the river. In most cases, the hydrilla was healthy with no obvious signs of stress. The only insect agent collected from the survey sites was *H. pakistanae*. This species occurred at minimal levels with only 300 immatures/kg and about four per cent of the leaves damaged.

Rehabilitation of a Shallow Lake (Big Muskego Lake, Wisconsin) via Draw-down: Sediment Response (WU 33309)

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We examined changes in surficial sediment physical and chemical composition, internal P loadings, and sediment resuspension dynamics due to lake draw-down and refill to promote macrophyte growth in shallow Big Muskego Lake, Wisconsin. 13% of the sediment area was exposed for ~1 year, while over 80% of the sediment area was exposed for a period of 6 months. Sediment moisture content and organic matter content decreased, while sediment density increased, due to lake draw-down suggesting consolidation of sediment and some oxidation of organic matter in the sediment. Porewater N and P, and laboratory-based rates of P release from sediment, increased substantially shortly after lake refill, but then declined 1 year later.
Although the lake was very susceptible to wind-induced resuspension before rehabilitation, draw-down and refill was accompanied by prolific submersed macrophyte growth which minimized sediment resuspension in the lake over a two year period.

Sediment Resuspension Dynamics in Canopy- and Meadow-forming Submersed Macrophyte Communities (WU 33128)

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We examined the effects of macrophyte beds dominated by a canopy-forming (*Myriophyllum sibiricum*) and a meadow-forming (*Chara*) species on shear stress near the sediment interface and resuspension in the large (1620 ha) and shallow (1.25 m) Lake Christina, MN. The surface sediments in the vicinity of an adjacent *M. sibiricum* and *Chara* station, located in the northern region of the lake, exhibited a high moisture content (85%), low sediment density (0.2 g/mL), and high organic matter content (16%), indicative of fine-grained, flocculent sediment. The critical shear stress ($_c$) of these sediments, measured experimentally in the laboratory using a particle entrainment simulator, was low (1.4 dynes/cm^2) indicating a strong potential for resuspension at moderate wind speeds in the absence of submersed macrophytes. Between late July and September, 1998, theoretical shear stress ( ), calculated using wind data and wave theory (i.e., assuming no macrophyte biomass in the lake to obstruct wave activity), exceeded the experimentally-derived sediment critical shear stress 16% of the time. However, *in situ* turbidity at both the canopy-forming *M. sibiricum* and meadow-forming *Chara* station was low and rarely increased when exceeded $_c$, indicating that both macrophyte beds reduced sediment resuspension in the lake. *In situ* shear stress, measured using calibrated gypsum spheres, was high near the open water lake surface during periods of high winds. However, it declined to near zero within the zone of *Chara* growth (30-40 cm) just above the sediment interface and was low both near the water surface and near the sediment interface in the canopy-forming *M. sibiricum* bed. Our results indicate that both canopy-forming and meadow-forming macrophyte communities can reduce sediment resuspension by dampening wave activity and shear stresses required to resuspend sediments.

Identification of male and female plants of *Egeria* sp. in Jupia Reservoir, Brazil

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The genus *Egeria* has two species, both submersed, dioecious, perennial and considered to be native in South America. *E. densa* is widely distributed around the world, since it remains one of the most used aquarium plants. *E. najas* is confined to its native range in South America. The two species produce large stands in some reservoirs in Sao Paulo State, Brazil and in one of those, they are a threat to the Jupia Hydro Electrical Plant, controlled by Companhia Energetica de Sao Paulo (CESP). Surveys of *E. densa* distribution outside its native range found only male plants. The purpose of this survey was to evaluate the proportion between male and female plants of *E. densa* and *E. najas* in Jupia reservoir, a modified environment within the native range of the species. The survey was conducted in at the end of the summer and revealed that both sexes of *E. najas* were present, but female plants were found in only one area where male flowers outnumbered females by 7:1. Male plants of *E. densa* were not found, and female plants often produced large stands together with *E. najas*. Blossoming of *E. najas* was higher than *E. densa*. Flowers randomly collected in sampled areas along the shoreline revealed that *E. najas* flowers outnumbered *E. densa* flowers by 9:1 The results of this survey will be considered in chemical and biological control and in genetic similarity studies, developed by CESP and Sao Paulo State University.

KEYWORDS: *Egeria densa*; *Egeria najas*; CESP.

Preliminary Studies of Propagule Survival in Water Chestnut Treated with the Penny Shredder System (WU 33029)

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Survival of propagules was studied as part of a field evaluation of the Penny Shredder System for control of water chestnut (*Trapa natans* L.). Water chestnut seeds, mature plants, and various plant parts were collected from control and treated sites in Lake Champlain, Vermont. Collected plant materials were cultured under growth chamber conditions (25°C, with simulated sunlight at 350 μE m^{-2} s^{-1} for 14 hrs d^{-1}) to assess viability as influenced by the flailing mechanism of the Penny System. Assessments of viability were based on weekly determinations of new growth, including flowering and new seed production. These studies along with on-site observations provide data supporting four main conclusions: 1) control methods preventing seed production can reduce reestablishment of water chestnut the next growing season; 2) the high mortality of green (immature) seeds released during shredder operations suggests that their contributions to recurrence are likely to be minimal; 3) because recovery is high among cut rosettes with roots and stems still attached, repeated shredder treatments may be needed in the field to maximize injury to larger plants; and 4) the Penny Shredder System offers a potentially useful means of control, however, impacts of the decomposition of water chestnut need to be resolved.

Impacts of Herbicide Use on Threatened and Endangered Plant Species (WU 33199)

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The invasion and spread of exotic species can jeopardize the growth and survival of many aquatic and wetland plants in the US. Surveys of selected Corps of Engineer (CE) Districts were conducted to identify threatened and endangered (T&E) aquatic plants (both state and Federal) that may be at risk as a result of exotic aquatic plant invasions. Nearly 100 plants have been categorized as T&E species that rely on submerged or shallow water environments, and may be at a high risk of extinction. Moreover, approximately 40 percent of CE water resource development projects identified exotic species as a major factor threatening their aquatic and wetland resources. Small-scale evaluations have been initiated to determine the species selectivity of aquatic herbicides against target exotic invaders, such as hydrilla, Eurasian watermilfoil, giant salvinia, and wild taro and on various threatened and endangered plants, such as Texas wild rice, and selected submersed species. Information from this effort will enable project managers to select and implement chemical strategies for managing nuisance exotic vegetation while minimizing impacts on sensitive plants species that share the same habitat.

Integrated Endothall-fungal Pathogen Treatment on Four Submersed Plants (WU 32953)

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An outdoor mesocosm experiment was conducted to evaluate the efficacy and selectivity of the herbicide endothall and the endemic fungal pathogen *Mycoleptodiscus terrestris* (Gerd.) Ostazeski (Mt), applied alone and in combination with one another against *Hydrilla verticillata* (L.f.) Royle (hydrilla), *Potamogeton nodosus* Poiret (American pondweed), *Potamogeton illinoensis* Morong (Illinois pondweed), and *Vallisneria americana* Michx. (vallisneria). Treatments included 0.5 and 0.25 mg l^{-1} endothall, 100 and 200 colony forming units (cfu) ml^{-1} Mt, combined treatments of endothall (both rates) with either 100 or 200 cfu ml^{-1} Mt, and untreated controls. Endothall alone at 0.5 mg l^{-1} was sufficient to reduce hydrilla growth by 67% 42 days after treatment; however an integrated application of 100 or 200 cfu ml^{-1} Mt plus 0.5 mg l^{-1} endothall reduced biomass by 92 to 97% compared with untreated plants. Treatment with 0.25 mg l^{-1} endothall plus Mt at 100 or 200 cfu ml^{-1} reduced hydrilla by 72 and 90% respectively, whereas 0.25 mg l^{-1} endothall alone was ineffective for reducing hydrilla growth. None of the treatments impacted the growth of vallisneria. In contrast, both pondweed species were sensitive to both rates of endothall and to all of the combined endothall-Mt treatments. For all plants, treatment with either rate of Mt alone did not significantly reduce plant biomass compared with untreated plants. Results show that integrating a low dose of endothall (0.25 mg l^{-1}) with 200 cfu ml^{-1} Mt significantly improved hydrilla control compared with either product applied alone, but provided limited selectivity on the non-target species included in this study.

Experimental Study on the Stresses of Eutrophication to the Growth of *Potamogeton maackianus A. Been*

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Decline of submersed macrophytes in a shallow Chinese Lake, Lake Donghu with the progress of eutrophication, occurred in the past 40 years. Laboratory aquarium experiments were conducted to study the stresses of eutrophication on the growth of *P. maackianus* A. Been, a dominant submersed macrophyte of the lake before the 1970s.

The plant had grown in aquaria at fertile sediment and high trophic water for six weeks. In low light stress experiment, light gradients of aquaria were similarly adjusted to that at six vertical depths of Lake Donghu. And to test stresses of reducing sediment and excessive water nutrients on the plant, three water trophic levels of NH_4-N, NO_3-N and PO_4-P were set. The experiments were triplicated.

Biomass growth of the plant was reversedly related to light intensity at the simulated depths of $\geq$ 1.0m ($r = 0.96$, $p < 0.05$, $n=7$) and was negative at the depths of $\geq$ 1.4m, indicating the low light stress zone were ca. 0.9-1.5m depths of the light intensities of the lake. Chlorophyll content, shoot length and density growth increased primarily with the increased stress and peaked at 1.2-1.3m depths, indicating alternation of adaptive strategies under low and high stress levels by *P. maackianus*.

Sediment redox potentials correlated negatively with the growth in total shoot length. Plant tissue N and P contents correlated negatively with the biomass growth. These indicate reduced shoot or biomass growth of submersed macrophytes at low sediment redox and excessive tissue N and P contents, suggesting that low sediment redox potential and excessive N and P contents accumulated by the plant are stresses of eutrophication to *P. maackianus*.
Negative relationship between the sediment redox potential and peroxidase activity was found *in P. macckianus*, indicating physiological injury of reduced sediments on the plant roots. Carbohydrate and chlorophyll contents were little affected by the increased tissue luxury N and P, showing no impacts of eutrophication on reserve of this plant.
Key words: Low light sediment redox potential excessive tissue nutrients growth biomass shoot length

Methods to Determine Dispersal Mechanisms for Hydrilla and Eurasian Watermilfoil (WU 33188)

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Once a new aquatic plant is introduced into a lake, reservoir, or river several factors can regulate both its dispersal within the aquatic system and its ability to establish at new sites. Field work on mechanisms of dispersal are currently being conducted on the San Marcos River (San Marcos, TX), Ray Roberts Reservoir (near Denton, TX) and other reservoir systems, and in pond studies at the Lewisville Aquatic Ecosystem Research Facility (LAERF), Lewisville, TX. Our methods on the San Marcos River include quarterly sampling at several sites progressing down the river to collect plant fragments as they move with the river flow. Spring Lake on the headwaters of the San Marcos River contains a healthy population of hydrilla as well as several other non-native and native aquatic plant species. Initial data indicate that hydrilla fragments decrease in abundance with distance downstream from Spring Lake. Experimental fragment traps are also being constructed and deployed into several lakes and reservoirs to capture and contain fragments as they disperse throughout the invaded system. We are also developing experimental systems to analyze dispersal mechanisms in controlled ponds at LAERF containing Eurasian watermilfoil (*Myriophyllum spicatum* L.) and hydrilla (*Hydrilla verticillata* (L.f.) Royle). Quantitative data collected from field and pond experiments will provide information on seasonal and environmental factors regulating dispersal of nonindigenous aquatic plant species.

Measurement Systems for Rapid Detection and Characterization of Aquatic Plants (WU 33118)

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Rapid, accurate methods for measuring the abundance and distribution of submersed vegetation are critical to the success of vegetation management strategies. The Submersed Aquatic Vegetation Early Warning System (SAVEWS), an ERDC-developed integrated hardware/software system consisting of digital hydroacoustic and global positioning system components, goes a long way toward meeting the requirement. Commercially available hardware components are linked with novel processing software to generate position-referenced depth and vegetation canopy descriptors which can be used to generate distribution maps. The basic SAVEWS has been operational for several years and is currently being used independently by several federal and state agencies. The basic system and its performance and usage are described. Technology transfer efforts to make SAVEWS more readily available to others, and developmental efforts to enhance its capabilities are presented.

Development of an Endemic Fungal Pathogen for Biological Control of Hydrilla (WU 32863)

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Mycoleptodiscus terrestris (Gerd.) Ostazeski, an endemic fungal pathogen of *Hydrilla verticillata* (L.f.) Royle (hydrilla) is currently being studied to determine the feasibility of its use as a bioherbicide. Laboratory studies are planned that will focus on substantially increasing fungal biomass through fermentation from the present $\log_{10}$ 6 colony-forming units (cfus) per milliliter to $\log_{10}$ 7-8 cfus ml^{-1}. Aspects of fermentation optimization under investigation are growth medium, growth parameters, and milling procedures. In addition, greenhouse studies are underway to determine fungal concentration and exposure time relationships for hydrilla control. Preliminary results indicate that low dose application rates of *M. terrestris* slurry containing approximately 200 cfus ml^{-1} require an 18 hour exposure time to significantly reduce above ground hydrilla biomass at four weeks post application. In contrast, fungal slurry containing 400 cfus ml^{-1} requires a six-hour exposure time to produce similar results.

Ecological Attributes of Exotic and Native Plant Communities (WU 33186)

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The objective of this Aquatic Plant Control Research Program work unit is to document the ecological attributes of exotic and native plant communities. This information is needed to help justify restoration of native aquatic plant communities. Replicate ponds have been vegetated with monocultures of hydrilla, Eurasian watermilfoil and giant salvinia or with native plants. In this presentation, water quality conditions occurring in each of the vegetation types will be contrasted and related to vegetative cover.

Establishment of Native Aquatic Plants: An Overview (WU 33084)

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The objective of this Aquatic Plant Control Research Program work unit is to develop guidance that will enable resource managers to successfully establish diverse communities of native aquatic plants. The success of establishment efforts will depend on the availability of suitable plant materials and the provision of long-term protection from herbivores. Ongoing efforts are focused on developing methods for producing plant propagules of selected species of submersed, floating-leaved, and emergent plants. Methods of plant establishment (including herbivore protection) under different types of conditions will be presented. The progress of several ongoing establishment efforts will be discussed.

Establishment and Competitive Ability of *Nelumbo lutea* in Relation to *Myriophyllum spicatum.*

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We thought *Nelumbo lutea* (lotus) might competitively displace *Myriophyllum spicatum* (milfoil) because it produces floating and emergent leaves which might 'shade-out' the submersed leaves of milfoil. In order to test this hypothesis, we needed to know establishment techniques and depth limits for establishing lotus.

In mesocosm tanks, we investigated effects of planting depth and reduced incident light on lotus seedlings in separate treatments. With decreasing light availability, mean shoot:root ratios increased. In depths greater than 1 meter, lotus survival decreased and shoot:root ratios increased significantly.

In a 0.7 hectare earthen pond with an established population of milfoil and a new population of lotus, we used transect observations to characterize changes in species composition over a growing season. Milfoil exhibited strong dominance early in the season, but lotus achieved dominance by fall. Depth effects were not significant for well-established lotus plants.

Competitive interactions between lotus and milfoil were investigated over two growing seasons in a container experiment located within a pond. Where established, lotus dominated in the presence of milfoil. However, lotus could not be established in depths greater than 1 meter.

Lotus is shown to competitively suppress milfoil when well established. To expect successful establishment of lotus from seedlings, planting depth and available light should be primary considerations.

Changes in Levels of Soluble Sugars During Sprouting of Vegetative Propagules of Hydrilla and Pondweeds.

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Many weedy aquatic plant species rely on vegetative structures for perennation. Turions, tubers, and winter buds contain stored materials and are typically produced underground. Understanding the processes associated with remobilization of stored reserves during sprouting would aid in timing application management techniques and development of novel management methods. *Potamogeton nodosus* winter buds, *P. pectinatus*, and *Hydrilla verticillata* (monoecious and dioecious types) tubers were placed in flasks containing water and put into a darkened growth chamber (18 C). The next day and at two to three day intervals for the next four weeks, 10 propagules of each type were retrieved. Propagules and dependent shoots were analyzed separately. Each fraction was weighed and selected samples (collected prior to or after sprouting) were extracted in 80% ethanol at 80 C for 1 hr. Soluble sugars were determined by HPLC. Except for *P. pectinatus*, propagules sprouted between 5 and 10 days after the experiment started. Regression analysis showed a significant decline in propagule fresh weights (fw) over time indicating consumption of stored materials. There was no significant change in tuber fw over time for *P. pectinatus* tubers. *P. nodosus* produced the most shoot material relative to initial propagule size. Qualitative and quantitative differences in soluble sugars among species were evident. Fructose, glucose, raffinose, and sucrose were present in *P. nodosus, P. pectinatus*, and *H. verticillata* (monoecious and dioecious types). Stachyose was present in all except dioecious *H. verticillata* and sorbitol was not detected in any sample. Fructose and glucose were the most abundant soluble sugars in *P. nodosus*, comprising > 80% of the total. In non-sprouted *P. pectinatus* tubers, raffinose and stachyose were dominant forms, accounting for 57% of soluble sugars. In other species stachyose was < 2% of soluble sugars. For both monoecious and dioecious *H. verticillata,* fructose and glucose contributed > 70% of soluble sugars. Sucrose was present in small quantities ranging from 1.7 to 8.9% of soluble sugars depending on the species. The concentration of soluble sugars was low (< 5 mg/mg fw) in non-sprouted propagules. Following sprouting soluble sugar concentrations increased within the original propagule. Soluble sugar concentrations in newly formed shoots was four times that in *P. nodosus* winter buds by day 14 and 1 to 1.5 times that in *H. verticillata* tubers by day 22. The striking increases in concentrations of soluble sugars in propagules and newly emergent leaf tissue suggest that the control of starch hydrolysis is a key metabolic control point during sprouting.

Comparison of Areal Production Rates of Two Mechanical Systems for Control of Water Chestnut in Lake Champlain

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Water chestnut (*Trapa natans*), an invasive, non-indigenous annual species, forms floating rosettes from which numerous viable seeds are produced during the growing season. Conventional mechanical harvesting operations have been successfully used in Lake Champlain to remove floating rosettes prior to seed maturation, thereby reducing regrowth potential for the following growing season. The major limitations of these conventional operations are: (i) the high cost per acre treated, relative to available funding and size of the infestation, and (ii) the low areal treatment rates, relative to the size of the infestation and the length of the "effective" operational control window. Due to these limitations, responsible agencies are interested in evaluating alternative control techniques. One promising technique, the Penny shredder system, treats the water chestnut plants *in situ* with a "mechanical action" that generates significant damage to water chestnut plants. This eliminates the time-consuming requirement of transporting the harvested plant material to shore. The "mechanical action" is achieved by an array of cutters (similar to a garden tiller) attached along a narrow cylinder approximately 0.5 meters in diameter x 2.5 meters in length. For comparison, the operational performance of both types of systems (i.e., a conventional harvester system and the Penny system) was determined on Lake Champlain during July 1999. The conventional harvester system consisted of a harvester, a dedicated transport unit (with storage capacity equal to a single harvester load), and an onshore conveyor. Distance from the harvest site to the conveyor was approximately 1.7 km. Water chestnut biomass at the 0.5 hectare site was estimated at 70.7 MT hectare^{-1}. The production rate estimate for the harvester system from this test was 0.065 hectares hour^{-1}. Fresh weight standing crop estimates at the Shredder system test site was 57.1 MT hectare^{-1}. The production rate estimate was 1.15 hectares hour^{-1} for a "single-pass" treatment and 0.64 hectares hour^{-1} for a "double-pass" treatment.

Oregon and Chilean Populations of *Egeria densa* are Genetically Similar

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Populations of the dioecious plant *Egeria densa* Planchon (Hydrocharitaccae) in Oregon (USA) and southern Chile were tested for genetic variability by random amplified polymorphic DNA (RAPD) fingerprinting. With one exception, little genetic variability was found within and among in the populations. Some of the Oregon genets were identical to Chilean samples at the level of 46 characters. These results suggest that *E. densa* exists as a series of pan-American clones. Only male plants have been found in Oregon, whereas both males and females have been found in Chile. An understanding of the biological basis for the extreme adaptability and aggressiveness of male *E. densa* and, conversely, the apparent lack of fitness in females, may provide insights into ways to control adventive populations of this invasive plant.

The Use of Stream Delta Surveillance as a Mechanism for Early Detection and Control of Eurasian Watermilfoil

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Eurasian watermilfoil (*Myriophyllum spicatum*) was discovered in three discrete locations in Lake George, NY in 1985. Although an exhaustive program to limit its spread and to study its impact upon the native plant community has been in place since 1988, approximately 6-15 new sites are discovered yearly. Because human activity in the basin has exacerbated water conditions in recent years, the rate of establishment and spread of milfoil has been of particular concern. Presently 134 locations have been found throughout the 192-mile shoreline encompassing the littoral zone. Yearly tributary surveys by SCUBA were instituted in 1988. One third of the 128 stream deltas have been surveyed each year. The survey has provided a definitive procedure for locating new sites with milfoil, including the establishment of a regular, defined search pattern. Stream deltas were chosen because they represent readily identifiable locations that historically harbor a diverse community of native aquatic plants. Such data have been used to approximate the rate of spread of milfoil through the lake basin as a whole. When all tributaries are taken collectively, in 1988 less than one quarter of the sites contained milfoil; by 1999 the number had doubled. Although management efforts have eliminated or reduced milfoil in 120 of the 134 known locations, reintroduction to prior sites have occurred in over 75% of the sites resurveyed in a three-year cycle. In 1999 Eurasian watermilfoil was ranked 18th by relative abundance (a function of mean percent cover) and 28th by frequency of occurrence for the 50+ species of submerged aquatics in the lake. The long-term implications of this research program are to 1) determine the rate of spread of an introduced species in an oligotrophic lake system, 2) assess the ecological impact of an introduced species upon the native plant community and 3) support evaluation of control measures.

Sagittaria Graminea: Emerging Aquatic Weed in Victoria, Australia

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Australia is one of the world's driest continents. Thus, water is a critical resource to agriculture and natural ecosystems. Exotic aquatic plants are critical issues in waterway management because of their impact on water quality, water delivery, and aquatic ecology. Arrowhead (*Sagitteria graminea*), is an aggressive plant introduced from North America which rapidly spreads in natural waterways and irrigation canals and drains where it causes disruption to the flow of water. It has become widely spread throughout the irrigation areas of southeastern Australia. It is an emergent, erect perennial plant growing up to 150cm, introduced from the Americas. Arrowhead is commonly found in shallow, slow moving creeks, canals and drains. It spreads rapidly, forming dense clumps, which may cause a slowing down of water to unacceptable rate. The rate spread is due to the fact that it has the ability to spread by seeds, rhizomes, and bulbs. The weed has continued to spread and populate new areas within northern Victoria. It is estimated that around AUS $ 600,000 has been spent to control arrowhead in canals in the Murray-Valley irrigation area over the past 10 years. Goulbourn-Murray Water is investigating potential control methods. Used of herbicide, 2,4-D and mechanical methods are effective and most effective rates and application times are to be determined.

Assessing Potential for Spread and Impacts of Eurasian Watermilfoil (Myriophyllum spicatum) in Lake Tahoe using in situ Transplants and Bioasays

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This project was conducted to determine the ecosystem effects on the invasion of Eurasian watermilfoil (*Myriophyllum spicatum*) at Lake Tahoe. Objectives of the study were to: 1) monitor the occurrence and spread of *M. spicatum* around Lake Tahoe, 2) estimate the potential for infestation of new areas around the lake, and 3) determine whether M. spicatum threatens lake water quality by enhancing the growth of algae. Plants from populations in the Tahoe Keys Marina and Meeks Bay were transplanted to five sites representing a range of physical characteristics and included both invaded and non-invaded sites. Responses to sites were highly variable, but all sites supported growth of *M. spicatum* except exposed sites with extreme wave action. Plants grew as well in non-invaded as sites currently invaded. Bioassay using naturally occurring phytoplankton suggested that the presence of *M. spicatum* enhanced productivity when measured by 14-C or *in vivo* fluorescence.