Abstracts

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Session I

A MESSAGE TO OUR PUBLIC: WHY AQUATIC HERBICIDES AFFECT AQUATIC PLANTS AND NOT US. Carole A. Lembi, Department of Botany and Plant Pathology, Purdue University, West Lafayette, IN 47907

One of the critical challenges in aquatic plant management is educating the public about the techniques that are used to control aquatic vegetation. Concern about the use of chemicals to control aquatic weeds is common, and unfortunately, sound scientific facts often fall by the wayside in an effort by some to denounce the used of pesticides. The purpose of this talk, which incorporates elements of botany, pesticide chemistry, and human health issues, is to convey the scientific principles behind aquatic herbicide and algicide treatments in a way that is understandable to lake association members. It is intended to provide enough factual information so that the listener can make decisions about the use of herbicides/algicides based on fact and not on fear. The message is basically as follows. Aquatic herbicides fall into two groups. One group (Sonar, Aquakleen, and Rodeo) is very specific to plant processes. In other words, there are metabolic processes that occur only in plants, not in animals. These herbicides affect plant processes but not animal processes; therefore, they tend to have very low mammalian toxicities. The second group (copper sulfate, Reward, Aquathol) are more general in their effects, and they can affect both plant and animal processes. Why then do we still use them? The keys are low doses, low persistence, and high water solubility. They are applied to water at such low doses that a person would literally have to drink hundreds of gallons of water to receive a toxic dose. The chances of this happening are almost nonexistent since these chemicals are removed from the water by sedimentation (copper, Reward) or by microbial breakdown (Aquathol) within a matter of days. Finally, these compounds do not partition into fatty tissues. Because of their high water solubilities, they stay in the urine, which passes right through the body and out. They do not build up in fatty tissues where they could cause long term health problems. Aquatic herbicides and algicides are not the answer for every aquatic weed problem, but there are sufficient scientific data indicating that, when used correctly and wisely, they do not cause human health problems.

Session II

AERF RESEARCH AND EDUCATION UPDATE. Kurt D. Getsinger, US Army Engineer Waterways Experiment Station, Vicksburg, MS 39180-6199

The Aquatic Ecosystem Restoration Foundation (AERF) has initiated research and educational efforts during the past year to promote the selective management of nuisance aquatic vegetation. Resources are leveraged to form Federal, state, academic, and private partnerships for improving the management of exotic pest species using environmentally-sound strategies. Over 15 projects and studies are currently funded and coordinated by the AERF, including development of product-specific control techniques, assessment of ecological impacts following management applications, and special symposia on the selective management of aquatic vegetation using herbicides. Established in 1996, the AERF is a non-profit organization dedicated to restoring and managing aquatic resources via research and development, public education, regulatory interactions, and public/private partnerships.

RENOVATE™ - POTENTIAL NEW HERBICIDE FOR SELECTIVE CONTROL OF CERTAIN AQUATIC PLANTS. Steve D. Cockreham, SePRO Corporation, Carmel, IN

In November 1997, the USEPA granted an Experimental Use Permit (EUP) for the use of Renovate™ for the selective control of woody plants and certain annual or perennial weeds in ponds, lakes, reservoirs, marshes, and wetlands, and the banks and shores of these sites. Renovate™ is the triethylamine salt formulation of triclopyr. It is a systemic herbicide that provides control of certain aquatic plants including Eurasian watermilfoil (*Myriophyllum spicatum*), purple loosestrife (*Lythrum salicaria*), alligatorweed (*Alternanthera philoxeroides*), and water hyacinth (*Eichhornia crassipes*). SePRO Corporation is implementing the EUP program and will review product information including field trial results, and an update on its registration by the USEPA.

REVIEW OF AQUATIC ENVIRONMENTAL FATE OF TRICLOPYR AND ITS MAJOR METABOLITES. B.A. Houtman, Dow AgroSciences, Indianapolis, IN, K.D. Getsinger, WES, Vicksburg, MS, D.G. Petty, NDR Research, D.R. Foster and B.S. Rutherford, Dow AgroSciences, Indianapolis, IN

Triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid) is a systemic compound currently being evaluated for use as a species-selective aquatic herbicide. Upon application to an aquatic system, triclopyr triethylamine quickly hydrolyzes to triclopyr acid, which subsequently degrades to 3,5,6-trichloropyridinol (TCP) and 3,5,6-trichloro-2-methoxypyridine (TMP). Field studies have shown that triclopyr is rapidly degraded in water, and at recommended use rates is not toxic to non-target organisms. Results from field dissipation studies conducted in reservoir, lake, riverine, and closed-pond systems indicate that degradation of triclopyr and its major metabolites is predictable and similar throughout the US. Total residues (triclopyr + TCP + TMP) accumulated for 3-14 days and then declined rapidly in finfish and shellfish. Residues in pond and lake water treated at 2.5 mg/L (proposed maximum rate) triclopyr rapidly declined with half-lives of 0.5-15.3 days. Results indicate that dietary risks to human populations that would consume fish or water from triclopyr-treated surface water would not be significant. The inherent ability of triclopyr to selectively control certain exotic weedy species, is expected to make triclopyr a viable option for restoring and managing aquatic ecosystems.

ENDOTHALL: NEW FORMULATIONS AND NEW USES. Gerald Adrian, Elf Atochem North America, Philadelphia, PA 19103

Elf Atochem has developed a new formulation of endothall under the trade name, Aquathol™ Super K Aquatic Herbicide. This product is being utilized in several states under Special Local Needs (SLN) 24-C labels. Aquathol™ Super K is a concentrated granular formulation containing 62% active vs. 10.2% active for the conventional Aquathol™ Granular Herbicide. This is the first herbicide registered to utilize super absorbent technology, with several benefits over the current clay formulation including reduced handling/storage, and less potential for exposure due to reduced amount required per area treated and reduced dusting. Full Federal registration for Aquathol™ Super K is anticipated in 1998. Hydrothol™ 191 Aquatic Herbicide and Algicide has been registered under SLN labels in Oregon, Arizona, and Nebraska for use in irrigation canals at rates to 0.2 mg/L, eliminating use restrictions associated with the current Hydrothol™ 191 label. Use of this product at 0.2 mg/L for 120 hr has proven effective against algae and weeds in western US irrigation canals. This use pattern can be achieved when combined with the Chemical Metering and Control System developed by the USBOR, and makes this technique a viable alternative for weed and algae control in irrigation canals. SLN labels are anticipated for Washington, Idaho, Nevada, and Colorado.

CLEARIGATE™ RESEARCH AND OPERATIONAL EXPERIENCE. Jim Schmidt, Applied Biochemists, Milwaukee, WI 53218

Clearigate™, an aquatic herbicide/algicide, has been widely evaluated in operational field applications and growth chamber studies since 1996. Dose/exposure time relationships have been determined for sago pondweed (*Potamogeton pectinatus L.*), a species commonly infesting irrigation systems in the Western US. Field work has included evaluation of a variety of application/dosing systems designed to meter product proportionate to water flow. Control of a number of other aquatic plant species in flowing water systems has been achieved at < 1 mg/L copper (label limit) from exposure times < 3 hours. Work in Southeastern US ponds and drainage canals have led to development of efficacious tank mix ratios with 2,4-D, Aquathol™, Hydrothol™ 191, and Reward™ aquatic herbicides on a variety of submersed and floating macrophyte species, plus several types of "resistant" algae. Combinations and ratios are being evaluated under controlled studies on sago pondweed, hydrilla (*Hydrilla verticillata* (L.f.) Royle), and Eurasian watermilfoil (*Myriophyllum spicatum* L.).

2,4-D REGISTRATION AND LABEL UPDATE. William M. Mahlburg, Nufarm Americas, Inc., St. Joseph, MO.

Aquatic plant management has included 2,4-D as means of chemical control for many years. Although registrations of several important formulations of 2,4-D are expected to continue into the future, users continue to ask questions about the timing of re-registration by EPA and the availability of label improvements sought by the user community. The re-registration timeframe now appears to be about 2000, but there are several waves of label improvements that may be feasible in the interim.

FASTEST™ CASE STUDIES: WHAT ARE WE LEARNING ABOUT RENOVATE™ AND SONAR™ . Alicia G. Staddon, SePRO Corporation, Carmel, IN

The utilization of the FasTEST™ immunoassay technology has enabled the aquatics industry to gain important knowledge and understanding concerning the use of the aquatic herbicide, Sonar™. This assay technique has evolved into a highly technical and reliable tool, providing new opportunities to optimize a wide array of Sonar™ treatments. Recently, immunoassay technology has been integrated into field evaluations to selectively control Eurasian watermilfoil (*Myriophyllum spicatum* L.) using the aquatic herbicide, Renovate™ , which is currently undergoing the USEPA registration review process. Data from new case studies utilizing FasTEST™ in Sonar™ and Renovate™ treatments will be introduced and discussed.

SELECTIVE STEM TREATMENTS WITH RODEO™ FOR CONTROL OF BRAZILIAN PEPPERTREE. Dennis H. Williamson, Monsanto Company, Raleigh, NC

Trials are underway in Florida to determine the capability of Rodeo™ Herbicide from Monsanto for control of Brazilian peppertree. Several mixtures of Rodeo™ with experimental surfactant MON 59120 are being applied as basal and modified stem treatments to determine the rate, timing and best method of application. Early results show excellent 3 and 6 month control of single stems from nearly all modified stem treatments and some treatments with basal applied rates of Rodeo™. Work will continue to determine the best fit response and to screen the activity of similar treatments on Australia pine and melaluca. Trials are being done in cooperation with the University of Florida, the South Florida Water Management District, and Metro-Dade Parks system.

AN IMMUNOCHEMICAL ANALYTICAL METHOD FOR ENDOTHALL, THE ACTIVE INGREDIENT IN AQUATHOL™ K AND HYDROTHOL™ 191 AQUATIC HERBICIDES

Janice K. Sharp, Timothy M. Formella, John C. Toth, Elf Atochem North America, Inc., Philadelphia, PA, Dale Onisk, Yi Zhou, Fouad Sayegh, and James W. Stave, Strategic Diagnostics Inc., Newark, DE

An immunochemical analytical method has been developed for endothall in water to replace traditional analytical methodology. Endothall has been an extremely difficult molecule to analyze. It is polar, charged at neutral pH, contains only carbon, oxygen and hydrogen, and therefore has no effective chromophore for detection. It also behaves much like natural sugars and organic acids found in plant and animal matrices. Traditional analytical method involves many steps, including derivatization with heptofluoro-p-tolyhydrazine, difficult clean-up steps, and GC-ECD. This method requires at least 2 days to complete and is not rugged as an enforcement method. Monoclonal anitbodies made to endothall are currently being used in a magnetic-particle format (Strategic Diagnostics, Inc.) to quantitate endothall as low as 10 µg/L. This method has been validated in surface waters and shows tighter CV's and better recoveries than the traditional method. Correlation results of the two methods will be discussed. A semi-quantitative form of the immunochemical method is being used as an on-site monitoring method for EVAC™ Biocide applications in industrial plants for removal of zebra mussels. The quantitative method is currently used in-house to characterize endothall dissipation patterns in water.

AQUATIC DISSIPATION MODELING OF ENDOTHALL. Janice K. Sharp, Chris Davis, Gerald Adrian, Elf Atochem North America, Philadelphia, PA 19103, Ron Biever, Springborne Laboratories, Inc., Wareham, MA 02571 Piyush Singh, Amy Ritter, W. Martin Williams, Richard Freelander, Waterborne Laboratories, Inc., Leesburg, VA 20175

Endothall dissipation in surface waters is complex and highly dependent upon amount applied, configuration and volume of treated area, water movement, weed density, and sediment type. Processes such as hydrolysis and photodegradation do not play a major role in endothall dissipation, and degradation of the molecule is predominantly via microbes and plant metabolism. Laboratory studies show that microbes act quickly to reduce endothall concentrations in water (half-lives 5-10 days), and that aquatic plants absorb and metabolize endothall at concentrations higher than found in surrounding water. Endothall field dissipation has been measured as total of all degradation and dilution processes. In partial lake treatments, endothall dissipates with half-lives < 1 day, while in closed, whole-treatment systems, endothall concentrations fell to undetectable levels in 3-5 days. Endothall has been observed to dissipate and pas through a 40-km length of canal after 35 hr. Computer modeling is proving to be a useful tool in predicting endothall residues over time and space, in both lakes and canals. USEPA approved models modified especially for endothall and endothall application scenarios (lakes and canals) are in the validation process. These models both show promise as methods to predict endothall residues at potable water intakes, irrigation gates, and other outflow scenarios in which endothall concentrations may be of concern.

REVIEW OF SONAR™ FALL APPLICATIONS FOR SELECTIVE CONTROL OF EURASIAN WATERMILFOIL. Tyler J. Koschnick, SePRO Corporation, Carmel, IN

One aquatic species causing major problems in the Northern US is the exotic submersed weed, Eurasian watermilfoil (*Myriophyllum spicatum* L.). Aquatic plant managers search for alternatives to control this invasive plant while minimizing impacts to native plant communities. A potential selective control technique currently being evaluated is a fall season application of Sonar™ . In theory, fall applications of Sonar™ might selectively control milfoil while reducing negative impacts on non-target native vegetation, due to fall dormancy of most native submersed plant species. Unlike many valuable native plants, milfoil is a perennial species that remains photoactive under the ice, and could be susceptible to herbicide uptake at that time. Preliminary data suggests that fall applications of Sonar™ were successful in controlling milfoil with minimal impacts on native vegetation. This paper will review the results of several applications conducted in Wisconsin, Indiana, Illinois, and Iowa.

SELECTIVE HYDRILLA MANAGEMENT USING SONAR™ . David P. Tarver, SePRO Corporation, Tallahassee, FL

Hydrilla (*Hydrilla verticillata* (L.f.) Royle) continues to spread in distribution and create severe environmental and economical problems. This exotic pest species affects the diversity and use of various aquatic areas differently. Aquatic flora found in waterfowl management sites may exhibit shifts from predominately annuals; planted mitigation ponds containing nursery emergent plants often experience decreased plant survival; and fisheries management systems may develop stunted sportfish populations once sufficient hydrilla densities exist. This paper will discuss the management objectives and results of several Sonar™ prescriptions and applications in order to selectively manage hydrilla.

THE BIOALGICIDAL POTENTIAL OF FRESH CUT ALFALFA AND REED CANARY GRASS ON SEVERAL ALGAL SPECIES. Joseph T. Marencik and Carole A. Lembi, Department of Botany and Plant Pathology, Purdue University, West Lafayette, IN 47907.

The bioalgicidal properties of several forages and straws were examined as an alternative to the use of copper containing algicides. The algistatic effects of barley straw have previously been documented. However, the availability of barley straw can be a problem. In response to this problem, an algal screen was developed to test other forages and straws that might also be effective bioalgistats or bioalgicides. Nine different forages and straws were tested on twelve algal species. The forages and straws that were assayed included barley, fescue, reed canary grass, alfalfa haylage, fresh cut alfalfa, rye, birds trefoil, wheat, and oats. The algal screen included *Anabaena, Ankistrodesmus, Euglena, Gloeocapsa, Navicula, Oscillatoria, Pithophora, Scenedesmus, Selenastrum, Spirogyra, Synechococcus*, and *Synedrea,* all grown in culture. The forages and straws, at a rate of 5 g dry material / L, were decomposed in barrels filled with water. The liquids from the decomposed plant material were then tested at monthly intervals for algistatic or algicidal properties. Fresh cut alfalfa and reed canary grass showed the most promising results. Growth rates were

significantly reduced for several of the target groups such as cyanobacteria and filamentous algae. Reductions of greater or equal to 50% of the control will be reported.

POTENIAL USE OF CATTAIL (*TYPHA DOMINGENSIS*) AND ITS ALLELOCHEMICALS IN THE BIOLOGICAL MANAGEMENT OF SALVINIA (*SALVINIA MINIMA*). Maria T. Gallardo and Dean F. Martin, Department of Chemistry, University of South Florida, Tampa, FL

Aqueous extracts of cattail plants (roots, stems, and leaves) as well as two of its allelopathic phenolics compounds (2-chlorophenol and salicyaldehyde) were found to inhibit the growth of *Salvinia* when incorporated to its growth medium in a short-term bioassay. Chlorophyll concentration, fresh weight, dry weight, and number of fronds were studied. The results suggest a strong inhibitory effect by components of *Typha*, especially of the root fractions. Results using pure allelochemicals are in agreement with the results obtained using the extracts. It is possible that cattail extracts or its allelochemicals could be used, under controlled conditions, for the biological management of *Salvinia*.

GROWTH OF BOG RUSH (*JUNCUS MEGACEPHALUS*). Yassin M. Al-Sodany and David L. Sutton, IFAS, University of Florida, Fort Lauderdale, FL 33314.

Bog rush (*Juncus megacephalus* Curtis) is included in the family Juncaceae. About 225 species of *Juncus* are widely distributed around the world and 90 of them occur in U. S. and Canada. A greater concentration of *Juncus* species falls in South America than elsewhere in the world. Because little information is available on growth of bog rush, plants were cultured with three fertilizers for 16 weeks in the summer and winter. Different amounts of sierra, agriform, and woodace fertilizers were added to sand held in pots without drainage holes. The pots were flooded and watered daily by an overhead irrigation system. Results will be presented on plant dry weight, number of plants, and the average height of the tallest plant measured every 4 weeks for the various fertilizer rates.

Session III

REVIEW OF RESULTS FROM STUDIES ON *EUHRYCHIOPSIS LECONTEI* UNDERTAKEN IN VERMONT AND MASSACHUSETTS 1989-1998. Sallie P. Sheldon, Department of Biology, Kent State University, Kent, OH

To date, results from our research has suggested that *Euhrychiopsis lecontei*, an aquatic weevil native to North America, may act as a biological control for Eurasian watermilfoil, *Myriophyllum spicatum*. In laboratory feeding trials, the weevil had a significant negative effect on *M. spicatum*. Results from two long-term research sites, and a series of lab studies on the effect of *E. lecontei* on native plants will be reviewed. Two field-enclosure trials suggest that the weevil can also have a negative affect on established *M. spicatum* in lakes. Because we found no significant negative effects of the weevil on North American aquatic macrophytes, beginning in 1993 we were allowed to start open water releases of the weevil. By the end of 1997 we have released > 400,000 weevils in 20 lakes. The effects of these weevil introductions/augmentations will be presented.

THE WEEVIL-WATERMILFOIL INTERACTION AT DIFFERENT SPATIAL SCALES: WHAT WE KNOW AND WHAT WE NEED TO KNOW. Robert Creed, Department of Biology, Appalachian State University, Boone, NC 28608.

The North American weevil *Euhrychiopsis lecontei* is being considered as a biological control agent for Eurasian watermilfoil. This native insect damages watermilfoil plants and is frequently associated with declining watermilfoil populations. Weevils and watermilfoil interact at four different spatial scales – 1) the level of the individual plant, 2) the level of beds within lakes, 3) lakes within geographical regions and 4) regions – and we still have much to learn about the interaction at these different scales. For example, at the level of the individual plant, we still do not know exactly how weevils bring about the demise of a watermilfoil plant. At the level of beds, we do not know how long it takes a weevil population to reach a density that will result in a significant reduction in watermilfoil biomass. Finally, at the regional level, we do not know if regional differences in lake productivity influence the weevil-watermilfoil interaction. It is

my hope that addressing these questions and filling in the gaps in our knowledge will lead to a better understanding of the interactions between these two species and lead to more efficient use of the insect in watermilfoil control projects.

IMPLICATIONS OF LIFE CYCLE TIMING IN *ACENTRIA EPHEMERELLA* AND *EUHRYCHIOPSIS LECONTEI* FOR THE BIOLOGICAL CONTROL OF EURASIAN WATERMILFOIL. Robert L. Johnson, Section of Ecology & Systematics, Cornell University, Ithaca, NY 14853-2701

A survey of 30 New York Lakes reports the aquatic moth larva *Acentria ephemerella*, and the aquatic weevil *Euhrychiopsis lecontei* feeding on Eurasian watermilfoil (*Myriophyllum spicatum* L.). Eurasian watermilfoil is the primary submersed aquatic macrophyte problem in New York because of this plant's ability, in the spring to rapidly elongate to the lake surface, and dominate the macrophyte community. Our survey in 1996 and 1997 records *Acentria* in all but one lake, with *Euhrychiopsis* in all lakes. We report severe herbivore damage by larval stages of these insects to Eurasian watermilfoil apical meristems stopping elongation. We record from lakes 0.01 to 0.03 *Acentria* and *Euhrychiopsis* per 25 cm long apical meristem. However, in a few lakes we record 0.3 to 0.9 *Acentria*, and in different lakes 0.3 to 2.4 *Euhrychiopsis* per 25 cm long apical meristem. Biomass data show a sudden decrease in Eurasian watermilfoil within Cayuga Lake, New York, a lake with high *Acentria* to low *Euhrychiopsis* numbers. During this recorded decline desirable native macrophytes increase while *Acentria* larvae feed from late April to late October. Three lakes with high *Euhrychiopsis* to low *Acentria* numbers have > 95% of their total biomass as Eurasian watermilfoil. One of these lakes, Dryden, experienced from mid-July to mid-August the typical watermilfoil damage caused by high numbers of *Euhrychiopsis*. At the end of August we found very few *Euhrychiopsis* eggs or larvae resulting in an early cessation of herbivory allowing watermilfoil to recover, and approach the water surface in late October without herbivore damage.

EUHRYCHIOPSIS LECONTEI DISTRIBUTION AND FACTORS INFLUENCING ITS ABUNDANCE IN WISCONSIN LAKES WITH EMPHASIS ON ITS USE AS A BIOLOGICAL CONTROL FOR EURASIAN WATERMILFOIL (*MYRIOPHLLUM SPICATUM*). Laura L. Jester, Michael A. Bozek, Wisconsin Cooperative Fisheries Research Unit, Stevens Point, WI, Daniel R. Helsel, Wisconsin Department of Natural Resources, Milwaukee, WI, Sallie P. Sheldon, Department of Biological Sciences, Kent State University, Kent, OH

The specialist aquatic herbivore *Euhrychiopsis lecontei* (the milfoil weevil) has been found to significantly reduce the biomass of Eurasian watermilfoil (*Myriophyllum spicatum*) and is currently being researched as a biological control agent for *M. spicatum*. In Wisconsin, research has focused on 1) *E. lecontei* distribution across lakes, 2) *E. lecontei* densities in lakes and limnological characteristics associated with their abundance, and 3) *E. lecontei* stocking as a practical management tool for controlling *M. spicatum*. The geographic distribution of *E. lecontei* is widespread with 45 new records among Wisconsin lakes containing *M. spicatum*. *E. lecontei* densities varied among 31 Wisconsin lakes from non-detectable levels to 2.5 weevils per stem of *M. spicatum*. Very few lake characteristics and only some milfoil characteristics were found to significantly correlate with *E. lecontei* densities across the 31 lakes sampled. The percentage of natural shoreline, the depth and distance from shore of the *M. spicatum* bed, the number of apical tips per stem of *M. spicatum*, and the percentage of broken apical tips per stem of *M. spicatum* were correlated with *E. lecontei* densities. Twelve Wisconsin lakes were also stocked with three different treatment levels of weevils (1,2, or 4 weevils per *M. spicatum* stem) in small study plots. Although some localized damage to the *M. spicatum* was observed at the end of the first treatment season, this portion of the study in ongoing and results are not yet complete.

TEMPORAL AND SPATIAL CHANGES IN MILFOIL DISTRIBUTION AND BIOMASS ASSOCIATED WITH WEEVILS IN FISH LAKE, WI. Richard A. Lillie, Wisconsin Department of Natural Resources, Monona, WI 53716.

This presentation represents a field case study of a natural decline in Eurasian watermilfoil, *Myriophyllum spicatum*, associated with the weevil, *Euhrychiopsis lecontei*. During the course of a seven year research-management project designed to examine the effects of selective mechanical harvesting of channels through dense milfoil beds on the fishery of a 100 ha, seepage lake, we observed a dramatic reduction in

the distribution and biomass of milfoil. Average milfoil biomass (based on an annual survey of approximately 600 sampling sites) declined by 40-50% during 1994-95 relative to the preceding three year period, during which biomass exceeded 500 g m^{-2}. Milfoil distribution shrank by a comparable amount based on interpretations of aerial photographs; however, most impacted areas contained stragglers or survivors that formed the nuclei for milfoil recovery in 1996-1997. During the "crash" of 1994-95, milfoil plants exhibited the now classical signs of weevil-induced damage, including darkened, brittle, hollowed-out growing tips, and arching of stems associated with subsequent loss of buoyancy. Monitoring and assessment of weevils suggest heaviest damage occurred near shore and subsequently fanned out into deeper water from core infestation sites as the season progressed and the weevil population expanded. The lack of strong correspondence between estimates of weevil abundance and average annual milfoil biomass suggests either a weakness in the current method of assessing weevil numbers or that some form of lag time exists between weevil damage and longer term impact on milfoil standing crop.

LABORATORY STUDIES ON MILFOIL WEEVIL HOST PREFERENCE, PERFORMANCE, AND PLANT DAMAGE, AND OBSERVATIONS ON MILFOIL DECLINES IN MINNESOTA. Raymond M. Newman, Department of Fisheries and Wildlife, University of Minnesota, St. Paul, MN 55108.

We studied the laboratory performance of the native weevil *Euhrychiopsis lecontei* and conducted field assessments to determine where and when the weevil may control Eurasian watermilfoil. For oviposition the weevil is highly specific to watermilfoils; it lays eggs on native and exotic milfoil, but rarely on other plants. *Euhrychiopsis* performs as well or better on the exotic Eurasian watermilfoil than on native northern and whorled watermifloils. Development depends on temperature, with a minimum development threshold of 10 °C, and 309 degree-days required for complete development. At typical Minnesota lake temperatures, 4-5 generations can be produced per summer. In tank experiments, initial stocking densities of 10-40 adults/m^2 reduced milfoil shoot and root biomass and carbohydrate stores in one month. Intensive field monitoring over the past 5 years has demonstrated one rapid decline (weevil density > 100/m^2) and one slow decline (weevil densities ~ 10-20 /m^2) of Eurasian water milfoil attributable to the weevil; at these sites native plant densities increased. At two other sites, weevil populations were very low and milfoil remained dense. At a fifth site, weevil densities of 30-100/m^2 have failed to control milfoil, perhaps due to lack of competition by native plants. At some sites weevil populations have not maintained adequate densities to effect longer term control, despite the high potential indicated by lab and tank experiments. Positive native plant community response may be equally important for sustained control. Factors limiting weevil populations and native plant community response need further investigation.

DISTRIBUTION OF THE WATERMILFOIL WEEVIL *EUHRYCHIOPSIS LECONTEI* IN WASHINGTON STATE. Mariana Tamayo, Christian E. Grue, School of Fisheries, University of Washington, Seattle, WA 98195, and Kathy Hamel, Washington Department of Ecology, Olympia, WA 98504.

The aquatic weevil *Euhrychiopsis lecontei* has been associated with declines of Eurasian watermilfoil (*Myriophyllum spicatum*). Studies indicate that *E. lecontei* is a watermilfoil specialist and that it can have a negative impact on Eurasian watermilfoil. A survey of 20 waterbodies within Washington in 1993 indicated that *E. lecontei* was present in the state. Given this, we began to evaluate the distribution of *E. lecontei* in Washington in 1996. We surveyed 38 waterbodies in 1996 and 50 in 1997. We found *E. lecontei* in nine lakes (24%) in 1996, two of which were in western Washington with the remainder in eastern Washington. In 1997, we found *E. lecontei* in 14 sites (13 lakes, I river; 28%), eight of which had weevils in 1996. Of the 14 sites, the majority (13) were in eastern Washington. In addition, most of the water bodies with weevils had an average of less than 0.4 adults per 5-minute survey per water body in 1996 and 1997. Our results suggest that *E. lecontei* is more widely distributed in eastern Washington than western Washington. Also, the densities of *E. lecontei* appear to be low in Washington.

FACTORS TO CONSIDER WHEN USING ENDEMIC BIOLOGICAL CONTROL ORGANISMS TO MANAGE EXOTIC PLANTS. Alfred F. Cofrancesco, U.S. Army Corps of Engineers, WES,Vicksburg, MS 39180.

Biological control is a management technique that employs living organisms to regulate or manage an unwanted target population. Two general approaches are widely used: an inundative or augmentative approach uses natural predators in large numbers to create stress sufficient enough to control or manage the target; or the classical approach that uses host specific insects, pathogens, or nematodes from the native range of the host to produce the stress necessary to regulate the target population. The inundative or augmentative approach has been used by pathologists who can mass produce large numbers of microorganisms. Insects have not often been employed in a similar manner because they are usually more costly to rear and field populations of native insects are subjected to an extensive number of their own natural predators. A number of questions often occur when attempting to use endemic insects to manage an exotic plant. In an attempt to utilize *Bellura densa* Walker, a native moth, to manage water hyacinth difficulties occurred. Rearing the agent in sufficient quantities was a problem along with numerous parasites and predators that naturally regulate populations of *Bellura*. No extended buildup of the moth population occurred under field conditions so damage to the target plant was only provided by the initial release. Another factor which needed to be considered was the impact that large numbers of *Bellura* would have on its native host *Pontederia cordata*. These concerns and others often make agencies hesitant to use a native insect in an augmentative role.

CONCLUDING REMARKS. John Madsen, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180.

A summary of findings and hypotheses that have been presented during the session will be given, with an emphasis on new studies or investigations that must be done to further the implementation of native insects for management of Eurasian watermilfoil. In addition, suggestions on critical processes or manipulations that could be made to enhance use of native insects as a management tool will be presented. The goal of the session is to research results to date from several investigators, and give potential direction not only for further research, but also indicate information needs and technological gaps to developing the use of native insects into an operational management tool for the control of Eurasian watermilfoil.

Session IV

AN OVERVIEW OF THE AQUATIC PLANT CONTROL RESEARCH PROGRAM. John W. Barko and Robert C. Gunkel, Jr., U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

The U.S. Army Corps of Engineers (CE) Aquatic Plant Control Research Program (APCRP) is the Nation's only federally authorized research program directed to develop technology for the management of non-indigenous aquatic plant species. The APCRP is designed to provide effective, economical, and environmentally compatible methods for assessing and managing problem aquatic plants that interfere with the valued uses of the waterways of the United States. Research efforts are currently focused on the development of advanced management strategies and applications for the submersed aquatic plants, hydrilla (*Hydrilla verticillata* (L.f.) Royle) and Eurasian watermilfoil (*Myriophyllum spicatum* L.). The APCRP is committed to the development, transfer, and implementation of aquatic plant management technologies, and will continue to lead the Nation in the future.

AN OVERVIEW OF THE ECOLOGICAL ASSESSMENT TECHNOLOGY AREA. John D. Madsen U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

The Ecological Assessment Technology Area has been actively involved in evaluating aquatic plant assessment techniques, dispersal mechanisms, revegetation techniques, ecological impacts of nonindigenous plant communities, and plant propagule success. In addition, researchers within this area are leveraging the expertise and resources within these research areas to assist other projects in addressing issues both nationally and locally. Researchers are also collaborating between technology areas within WES, and with other institutions, to address plant management problems with an interdisciplinary approach.

AN OVERVIEW OF THE BIOLOGICAL CONTROL TECHNOLOGY AREA. Alfred F. Cofrancesco U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

This technology area has been developed to identify and release biological control agents for the management of noxious and nuisance aquatic plants. Our current focus is the management of Hydrilla and Eurasian watermilfoil with both exotic and native organisms. We are also creating evaluation procedures that will allow the documentation of impact caused by both insects and pathogens. Studies are also being conducted on processes that allow biological control technology to be easily incorporated into integrated pest management plans.

AN OVERVIEW OF CHEMICAL CONTROL TECHNOLOGY. Kurt D. Getsinger, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

Research and development activities in the Chemical Control Technology Area concentrate on developing and evaluating chemical products and application techniques that will improve the management of nuisance aquatic plants. Current research efforts focus on developing species-selective control of target plants, precision herbicide application techniques, potential impacts on threatened and endangered plant species, and integration of control strategies with ecological principles. Studies are conducted in controlled-environment chambers, greenhouses, hydraulic flumes, outdoor mesocosms, experimental ponds, and in the field. Cooperators and partners include Federal, state, and local agencies, Corps of Engineer Districts, academic institutions, and the private sector. Interactions also occur with Federal and state regulatory agencies. Proven benefits derived from studies and interactions include the accepted use of lower herbicide rates (without sacrificing target plant efficacy), development and use of new formulations and application techniques, improved environmental compatibility, and reduced application costs

AN OVERVIEW OF THE MANAGEMENT STRATEGIES AND APPLICATIONS TECHNOLOGY AREA. John W. Barko and Robert C. Gunkel, Jr., U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

Activities in the Management Strategies and Applications Technology Area are directed toward integration and adaptation of technologies to the needs of aquatic plant management. Specific activities relate to the integrated use of herbicides and pathogens, ecological relationships between aquatic plants and fish, operational procedures for rapid detection and mapping of submersed aquatic plants, evaluation of quantitative aquatic plant assessment techniques, and the estimation and mapping of the probability of aquatic plant colonization. Research efforts in this area are integrated with efforts conducted in other technology areas within the Corps of Engineers Aquatic Plant Control Research Program.

Poster Session

HIGH-TEMPERATURE EFFECTS ON GROWTH AND PROPAGULE FORMATION IN HYDRILLA BIOTYPES (WU# 33029). Dwilette G. McFarland and John W. Barko, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

In comparative greenhouse studies, growth and propagule formation were examined in monoecious hydrilla [*Hydrilla verticillata* (L.f.) Royle] and dioecious hydrilla, at three temperature levels (25, 30, and 35 C) and contrasted over three periods of growth (8, 12, and 16 weeks). For both biotypes, total biomass was similarly high at 25 and 30 C; maximum biomass occurred in those treatments by 12 to 16 weeks. Dioecious hydrilla produced no tubers at 35 C, and no axillary turions at 30 C and above. Monoecious hydrilla produced no turions at 35 C, but the number of tubers, though reduced in that treatment, was relatively high. Monoecious hydrilla may be better adapted to high temperatures than previously shown, and its range in the US could increasingly overlap that of dioecious hydrilla in the south.

TECHNIQUES FOR ESTABLISHING NATIVE AQUATIC PLANTS (WU# 33084). R. Michael Smart[1] and Gary O. Dick[2], [1]U.S. Army Engineer Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX. [2]University of North Texas, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

The objective of this work unit is to develop methods for establishing desirable native aquatic plants in multi-purpose reservoirs. Methods to be discussed include production of transplant materials, planting, and protection from herbivores during early establishment. Early results of several aquatic plant establishment efforts in Corps reservoirs will be presented. Ongoing efforts, including a state-wide initiative to establish native aquatic plants to enhance aquatic habitat in the public waters of Texas, will also be described.

ECOLOGICAL EFFECTS OF EXOTIC AND NATIVE AQUATIC PLANTS (WU# 33186).R. Michael Smart[1], Gary O. Dick[2], Robert D. Doyle[1], John D. Madsen[3], David R. Honnell[4],and Joe R. Snow[1],[1]U.S. Army Engineer Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX. [2]University of North Texas, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX. [3]U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. [4]AsCl Corporation, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

While the harmful effects of nuisance exotic plants on water resources are well known, their environmental and ecological effects are not. In fact, many sportsmen are of the opinion that exotic species like hydrilla provide desirable aquatic habitat. This work unit will provide an evaluation of the water quality and habitat aspects of selected exotic and native submersed aquatic plants. The proposed multi-year pond study will be described, and preliminary data obtained from experimental ponds and from a hydrilla-infested reservoir will be presented.

VEGETATIVE SPREAD OF HYDRILLA COLONIES (WU# 33188). John D. Madsen[1] and Dian H. Smith[2], [1]U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, [2]U.S. Army Engineer Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

Stolons and fragments are two vegetative mechanisms by which *Hydrilla verticillata* expands a colony. These two mechanisms of spread were studied in outdoor ponds located in Lewisville, TX. Stolons were determined to be the predominant mechanism for localized expansion. While some fragments were produced, fragments accounted for only 0.1% of the establishment of rooted plants in new quadrats. Spread occurred between June and November of each year, with rates of spread higher in the second season.

MACROPHYTE INFLUENCES ON SEDIMENT RESUSPENSION IN SHALLOW AQUATIC SYSTEMS (WU# 33128). William F. James[1], John W. Barko[2], and Harry L. Eakin[1], [1]U.S. Army Engineer Waterways Experiment Station, Eau Galle Aquatic Ecology Laboratory, Spring Valley, WI. [2]U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

By inhibiting sediment resuspension, submersed aquatic macrophytes play an important role in improving water quality in shallow lakes and impoundments. In the absence of aquatic macrophytes, these systems are dominated by sediment resuspension. The establishment of macrophytes in these systems tends to be associated with a clear water state and low phytoplankton biomass, due to macrophyte-mediated reduction in sediment resuspension. Thus, the establishment and maintenance of aquatic macrophyte communities is critical for water quality in these systems. We provide an example of the role submersed macrophytes can play in reducing sediment resuspension in a shallow USACE impoundment, Marsh Lake, Minnesota.

MACROPHYTE INFLUENCES ON HYDRODYNAMICS IN AQUATIC SYSTEMS (WU# 33201). William F. James[1], John W. Barko[2], and Harry L. Eakin[1], [1]U.S. Army Engineer Waterways Experiment Station, Eau Galle Aquatic Ecology Laboratory, Spring Valley, WI. [2]U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

Submersed aquatic vegetation can strongly influence water residence time, current velocities, and flow fields by imparting resistance to water movement and affecting the distribution of heat in the water column. Increased hydraulic residence time induced by high levels of aquatic plant biomass may significantly reduce the dispersion and dilution of dissolved and particulate materials, particularly in rivers. Dense canopy-forming submersed macrophytes can also contribute substantially to the development of strong thermal gradients, promoting water circulation, even in the absence of wind. Examples of water circulation patterns in macrophyte beds are provided .

INSECT BIOLOGICAL CONTROL AGENTS (WU# 33028). Alfred F. Cofrancesco, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

This poster will present an overview to the use of insect biological control agents for the management of submersed plant species. Major research directions include determining effectiveness of *Hydrellia pakistanae* in stressing and slowing growth of hydrilla, development of large-scale rearing procedures for *Hydrellia pakistanae*, and the evaluation of three new species of herbivores from Southeast Asia. Plant quality, predation/parasitism, and temperature are being examined as potential factors that may reduce the development of damaging populations of *H. pakistanae*. Mass rearing techniques include the development of large temperature controlled greenhouse rearing systems and the use of small ponds as nursery areas. The three agents are being evaluated for host specificity, impact during laboratory rearing, and ability to reproduce completely in an aquatic situation.

PLANT PATHOGEN BIOCONTROL RESEARCH ON HYDRILLA AND EURASIAN WATERMILFOIL (WU# 32863). Judy F. Shearer, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

Fungi collected from hydrilla (*Hydrilla verticillata*) and Eurasian watermilfoil (*Myriophyllum spicatum*) in the People's Republic of China in 1994 and 1995 were screened for pathogenicity in containment during 1996. More than 65% of the isolates screened (66 of 97) caused some damage. Of 13 isolates assigned a rating of '3' or more, five caused the same damage when tested again. Of these five, one was a *Phoma* sp. from hydrilla collected in Qiao Zhuang. The remaining four isolates were collected from the Huai-roi Reservoir on milfoil, three being *Mycoleptodiscus terrestris* and the other was a *Cylindrocladium* sp. Small scale testing of an endemic pathotype of *M. terrestris* formulated into a biocarrier and extruded into a dry granule reduced above ground biomass of hydrilla 88, 95 and 99 % when applied at low, medium or high dose rates, respectively. Preliminary results indicate that the fungal agent maintains viability in the dry granule up to 3 months post extrusion.

NATURALIZED AQUATIC INSECTS IMPACTING EURASIAN WATERMILFOIL (WU# 33189). Alfred F. Cofrancesco, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

This poster will present information on naturalized insects impacting Eurasian watermilfoil. During its first year this work unit has attempted to address two key components. First to bring together the key researchers working on native insects that are impacting Eurasian watermilfoil in a Special Session at the APMS meeting " The Use of Native Insects for the Management of Eurasian watermilfoil". This forum will be the first attempt to evaluate the research that has been conducted throughout the United States on agents impacting Eurasian watermilfoil. The second component of this work unit will examine the impact of the native weevil *Euhrychiopsis lecontei* Dietz from different regions of the United States.

EFFECTS OF BIOCONTROL AGENTS ON THE COMPETITIVE INTERACTIONS BETWEEN NUISANCE EXOTICS AND DESIRABLE NATIVE AQUATIC PLANTS (WU# 33117). Michael J. Grodowitz[1], Robert D. Doyle[2], and R. Michael Smart[2], [1]U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. [2]U.S. Army Engineer Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

This research will investigate the impacts of biocontrol agents on the long-term competitive interactions between native and exotic species. Initial studies are currently being implemented utilizing large mesocosm tanks and will focus on the interactions between hydrilla and *Vallisneria americana* with and without the presence of *Hydrellia pakistanae*. By stressing hydrilla with significant insect feeding damage, growth and production of hydrilla should be reduced, thereby enabling *Vallisneria* to out-compete hydrilla during an establishment period and to maintain this advantage over several growing seasons. Future studies include examining such relationships under field conditions and with several different species of native plants.

POPULATION MANAGEMENT OF TRIPLOID GRASS CARP (WU# 33200). James P. Kirk, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

Triploid grass carp, *Ctenopharyngodon idella*, can eliminate target vegetation in large reservoir systems. However, improvements in regulating population density and defining emigration potential are needed to make this fish a more effective management tool. Studies are on-going in the Santee Cooper reservoirs, South Carolina, where triploid grass carp have been stocked over 10 years resulting in a reduction of hydrilla, *Hydrilla verticillata*, from a high of almost 18,000 ha to 250 ha in 1997. As hydrilla declines, there is a greater potential that grass carp will move extensively in search of food. Beginning in 1998, telemetry studies will measure emigration potential of this fish into the Cooper River, an estuarine river used as a spawning site for many resident and anadromous fish. Concurrent studies will evaluate an injectable rotenone pellet that can be used to limit lifespan. This tool, if feasible, will have substantial importance in regulating triploid grass carp density and can potentially alleviate problems associated with over-stocking. The results of our studies can make triploid grass carp a much more effective management tool and will address environmental concerns

SELECTIVE USE OF HERBICIDES (WU# 32841). John G. Skogerboe[1], Kurt D. Getsinger[2], R, Michael Smart[1], Mike D. Netherland[2], and Gary O. Dick[3], [1]U.S. Army Engineer Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX. [2]U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. [3]University of North Texas, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

Herbicides can often be used to selectively remove exotic weedy vegetation from an aquatic system, allowing unaffected native plants to proliferate and occupy the vacant niche. Studies are being conducted in outdoor mesocosm systems at the Lewisville Aquatic Ecosystem Research Facility, TX, to determine the species-selective potential of registered and EUP aquatic herbicides (e.g. fluridone, triclopyr, endothall, and others). Results of completed mesocosm studies indicate that application of low treatment rates of fluridone or triclopyr to mixed plant communities consisting of Eurasian watermilfoil, *Vallisneria*, sago pondweed, American pondweed, water star grass, and *Elodea*, can selectively control Eurasian watermilfoil. These results are currently being evaluated under field conditions in the northern U.S. Endothall selectivity studies are in progress.

HERBICIDE DELIVERY SYSTEMS: EVALUATION OF SONAR SRP FORMULATION (WU# 32437). Michael D. Netherland[1] and David R. Honnell[2] , [1]U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. [2]AsCI Corporation, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

The slow-release fluridone pellet (Sonar SRP) is currently the only aquatic herbicide formulation that demonstrates controlled-release properties. A better understanding of SRP performance will improve both predictability for species-selective control and recommendations for spot treatments. Studies were conducted at the mesocosm and pond-scale to determine factors that influence the release and distribution of fluridone following an SRP application. Comparison of SRP and liquid fluridone treatments show distinct differences in short- and long-term trends in herbicide concentrations and distribution. By maintaining low levels of fluridone near the sediment/water interface following an SRP application, re-establishment of hydrilla from sprouting tubers was prevented for over 1 year. Sampling methods developed for these studies will also allow for improved determination of herbicide residues following granular applications of 2,4-D and endothall.

EVALUATION OF WATER TEMPERATURE EFFECTS ON HERBICIDE EFFICACY (WU# 33187). Michael D. Netherland[1], Chetta S. Owens[2], John D. Skogerboe[3], and John D. Madsen[1] , [1]U.S. Army Waterways Experiment Station, Vicksburg, MS. [2]AsCI Corporation, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX. [3]U.S. Army Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, Lewisville, TX

Cool water temperatures are known to inhibit the efficacy of contact herbicides. However, exotic species such as *Potamogeton crispus* L. and *Myriophyllum spicatum* L. often thrive at cooler water temperatures when native species remain dormant. In addition, current management practices are not impacting

production of *P. crispus* turions which allow for reinfestion of an area each year. Initial greenhouse studies were conducted to determine effects of water temperature (10, 15, and 20 C) on the efficacy of diquat and endothall for control of *P. crispus*. While results indicate that no differences in biomass reduction were noted between 15 and 20 C, efficacy was inhibited at 10 C using both products. In contrast to biomass results, all treatments resulted in a significant reduction in turion production. Preventing turion production is a key to successful long-term management of curlyleaf pondweed, and these results suggest that the timing of contact herbicide use may play a role in reducing the turion bank.

IMPACTS OF HERBICIDE USE ON THREATENED AND ENDANGERED PLANT SPECIES (WU# 33199). Linda S. Nelson and Michael D. Netherland, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

The invasion of the exotic species hydrilla (*Hydrilla verticillata*) in the San Marcos River, TX, has been identified as a major threat to the survival and recovery of Texas wild-rice (*Zizania texana*), a federally-listed, endangered plant species. Herbicides are effective for managing hydrilla infestations, however the direct impact of such treatments on Texas wild-rice is unknown. Results of ongoing greenhouse studies will determine which available aquatic herbicides will provide selective removal of hydrilla with minimal effects to Texas wild-rice. Surveys of selected Corps of Engineers Districts will also be conducted to identify other threatened and endangered aquatic and wetland plants (both state and Federally-listed species) that may be at risk as a result of exotic plant invasions. Information gathered from this research effort will enable project managers to select and implement chemical control strategies for managing nuisance exotic vegetation while minimizing the impact on sensitive plant species that share the same habitat.

INTEGRATED CONTROL: POND EVALUATION OF *MT,* FLURIDONE, AND COPPER COMBINATIONS FOR CONTROL OF HYDRILLA (WU# 32953). Michael D. Netherland and Judy F. Shearer, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

Laboratory and mesocosm studies have demonstrated the potential for combining the endemic fungal pathogen *Mycoleptodiscus terrestris* (*Mt*) with the systemic herbicide fluridone for improved hydrilla control. To verify these results, scale-up studies were conducted in a series of small ponds (0.04 acre) at the Center for Aquatic Plants in Gainesville, Florida. Treatments included *Mt,* fluridone, and copper alone, and combinations of *Mt*/fluridone, and copper/fluridone. *Mt* and fluridone treatments alone and in combination provided poor efficacy in these trials. The dense canopy of hydrilla in the ponds contributed to poor mat penetration and coverage of the liquid *Mt* formulation, as no obvious signs of infection were observed. Moreover limited hydrilla growth in the densely covered ponds resulted in slow activity and onset of fluridone symptoms, both alone and in combination with *Mt*.. In contrast, combination treatments of low rates of copper and fluridone were effective in providing immediate biomass reduction and subsequent season-long control of hydrilla. Research on formulating the *Mt* into a granular is ongoing to allow for improved coverage and infection.

RESPONSE OF FISHES TO CHANGES IN PLANT COMPLEXITY AND DISTRIBUTION (WU# 32944). K. Jack Killgore, U.S. Army Engineer Waterways Experiment Station Vicksburg, MS 39180

Aquatic plant management directly alters underwater spatial complexity which in turn influences reproductive success, growth, and density of fish. Field and pond studies have examined these attributes of fish populations to help develop sound fishery management concepts in vegetated water bodies. Results of our studies can be used to predict the response of fishes to varying degrees of plant complexity, particularly if the underwater landscape is characterized. In general, species diversity and abundance of the fish community will increase if plant management focuses on increasing interstitial spaces within dense plant beds while preserving native plants.

MEASUREMENT SYSTEMS FOR RAPID DETECTION AND CHARACTERIZATION OF SUBMERSED AQUATIC VEGETATION (WU# 33118). Bruce M. Sabol, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

Commercially available digital echo sounder, global positioning system, and personal computer components were linked to develop a system for measurement and characterization of the shallow water aquatic environments. Custom software allows processing of the digital echo sounder signal to detect submersed aquatic vegetation and characterize the vegetation canopy geometry, and to classify exposed bottom sediments. Processed outputs are coupled with mapping software to generate maps in near real time. Several case studies are presented to illustrate current and developing applications for the system.

FIELD EVALUATION OF QUANTITATIVE AQUATIC PLANT ASSESSMENT TECHNIQUES (WU# 33127). R. Michael Stewart and John D. Madsen, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

We are evaluating quantitative aquatic plant assessment techniques for use in both resource and aquatic plant management areas. The objectives are: (1) to prepare a compilation and detailed description of routinely utilized quantitative aquatic plant assessment techniques, (2) to evaluate, via side-by-side field demonstrations, preferred techniques for several of the typical assessment needs and (3) to provide a final instruction report outlining both: (a) the strengths and weaknesses of each quantification technique in regards to specific assessment needs and (b) the recommended quantification technique for specified assessment needs.

METHODS FOR DETERMINING AND MAPPING THE PROBABILITY OF AQUATIC PLANT COLONIZATION (WU# 33119). Rose Kress, Jerrell Ballard, Jr. and Bruce Sabol, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180

The objective of this research is to develop methods to estimate and map the probability of aquatic plant colonization within a waterbody in response to specified management options. A combination of spatial analysis and geo-statistics is used to quantify the combined effect of multiple environmental factors affecting plant colonization as a measure of the probability (likelihood) of colonization at any (or all) locations in the waterbody. These techniques will provide a method to directly compare the effects of a range of management options on plant distributions and will establish the framework for risk-based aquatic plant control decision making.

ESTIMATING WHOLE LAKE SUBMERSED MACROPHYTE ABUNDANCE: COMPARISON OF APPROACHES AND REQUIRED SAMPLE SIZES. Kerry L. Holmberg, Raymond M. Newman, and John L. Foley. Department of Fisheries and Wildlife, University of Minnesota, St. Paul, MN 55108.

Gathering accurate data on whole lake submersed macrophyte occurrence and abundance can be costly and time consuming. We evaluated several approaches to assess macrophyte abundance and estimated sample sizes needed for field surveys. Quantitative biomass ($n>40$) and relative density measurements (0-5 rating, Jessen and Lound 1962) using a hook or rake ($n>99$) were obtained from each of three shallow (<3m, 57-1,619 Ha) lakes in Minnesota. Relative density was related to biomass for common species but the fit was poor and varied among lakes. There were no differences between hook and rake density estimates for seven of the eight most abundant species (paired t-tests). There was no difference between our hook densities ($n=105$) and rake densities ($n=35$) collected in the same lake by the Minnesota DNR for the six most abundant species. Sample sizes needed for standard errors of Y% of the mean were calculated from current and historical data from 47 lakes ($N=S^2/(Y)^2*X^2$). At lower frequencies (<60%) and relative densities (<2), sample sizes required decreased logarithmically with frequency of occurrence and density. At higher densities or frequencies, sample size needed decreased sharply: for the most common species 10-15 samples were adequate for 10% error and <5 samples for 20% error. The Jessen and Lound relative density method is robust and yields consistent results, but is not a precise predictor of biomass. Estimates of relative density can be obtained with a reasonable number of samples for abundant species, however for less abundant species very large sample sizes (100-5,000) are required.

USING VIDEOTAPED TRANSECTS TO ESTIMATE ABUNDANCE AND DISTRIBUTION OF SUBMERSED AQUATIC PLANTS IN FALL RIVER, CALIFORNIA. D. Spencer and G. Ksander, USDA-ARS, Davis, CA 95616

Using an underwater viewing device, we videotaped transects of submersed aquatic plants during two years in Fall River, California. Less than eight hours on the river were required to collect more than 50 transects in an eight km section of the river. Videotapes were viewed upon return to the laboratory and species frequency determined. Viewing required about 50 hours, but could be done at the laboratory instead of in the field. This technique yielded very clear pictures of the plants and the river bottom and distinguishing plant species was not difficult. Using this technique in conjunction with a global positioning system, we were also able to develop vegetation maps. Species frequency values were comparable to those collected by other workers using different techniques and sensitive enough to reveal year to year differences.

SEASONAL VARIATION IN C, N, AND TOTAL PHENOLIC ACID CONTENT FOR EURASIAN WATERMILFOIL. D. Spencer and G. Ksander, USDA-ARS, Davis, CA 95616.

We compared water temperature and Eurasian watermilfoil (*Myriophyllum spicatum*) characteristics for plants from a shallow pond in Davis, California and the Truckee River, near Tahoe City, California. Milfoil tissue C was similar for plants from both sites, but overall mean tissue N was lower for plants growing in the Truckee River (1.82%, SD = 0.51%, n = 65) than for those growing in the Davis pond (2.07%, SD = 0.54%, n=669). Patterns of seasonal fluctuation in tissue N were also different. Phenolic acid content of Truckee River plants was similar (166 μM/g) to those from the shallow pond (185 μM/g), and was positively, but weakly, correlated with tissue C. Mean monthly water temperature for the Truckee River site was less than 19.3 °C during 1997. Warmest water temperatures occurred in August and September at this site and coincided with low levels of tissue N. During a 29-month period beginning January, 1994, mean monthly water temperature for the Davis pond exceeded 19.3 °C, only during July-September, 1995. Tissue N was generally greater during summer for watermilfoil growing in the pond. Temperature differences for the pond and river sites imply that potential biological control agents such as, the watermilfoil weevil, may have different developmental rates in these habitats. Based on published results with another aquatic weevil, the differences in tissue N for milfoil growing at these two sites, might also contribute to different development rates. For example, a weevil that feeds on hydrilla increased its relative growth rate by 50% when fed plant material with 3.5% N versus plant material with 2% N.

Session V

EVALUATION OF FOUR HERBICIDES FOR MANAGEMENT OF WATER HYACINTH AND AMERICAN FROGBIT. John D. Madsen[1], Chetta S. Owens[2] and Kurt D. Getsinger, [1]U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180, [2]AScI Corporation, Lewisville Aquatic Ecosystem Research Facility, RR3 Box 446, Lewisville, TX 75056

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms), is an introduced floating aquatic plant which spreads aggressively throughout an aquatic ecosystem due to the production of daughter plants. American frogbit (*Limnobium spongia* (Bosc) Steudel) is a native, floating aquatic plant that can spread rapidly throughout an aquatic ecosystem, generally following herbicide application to control water hyacinth. Both aquatic plants form dense canopies that can block navigation, degrade habitat and water quality, and provide breeding areas for mosquitoes. Herbicide demonstrations were conducted to compare the efficacy of the registered aquatic herbicides, glyphosate, 2,4-D, diquat and triclopyr (currently under an Experimental Use Permit). Water hyacinth was treated at the lowest recommended use rate during early spring and late summer. Water hyacinth biomass reduction was significant for all herbicides from the early spring treatments, but late summer treatments were less effective. American frogbit was treated at 25, 50 and 100% of the full label rate. American frogbit control was good to excellent using diquat and triclopyr at all treatment rates.

EFFICACY OF CLEARIGATE AND REWARD ALONE AND IN COMBINATION, ON FREE-FLOATING PLANTS. Stratford H. Kay and Steve T. Hoyle, Department of Crop Science, North Carolina State University, Raleigh, NC

Studies were conducted to evaluate the efficacy of Clearigate, alone and tank mixed with Reward, for control of duckweed (*L. perpusilla*), watermeal (*Wolffia* spp.), and mosquito fern (*Azolla caroliniana*). Testing was conducted in situ using one-meter square floating frames constructed of PVC pipe and anchored in place in the pond. A hand spray bottle was used to apply either 4 gal/a Clearigate, 2 gal/a Reward, or a mixture of these products at the same application rates for each product alone. Both herbicides, alone or tank mixed, gave good control of the duckweed and mosquito fern but had little effect on the watermeal.

RESIDUAL EFFECTS OF HERBICIDES IN TREATED WATER HYACINTH USED AS MULCH. Randall K. Stocker and William T. Haller. Center for Aquatic Plants, University of Florida, Gainesville, FL 32653-3071.

There is concern in some parts of central Africa that herbicide treated water hyacinth might be used as a mulch in fruit and vegetable production, and that herbicide residue could affect crop productivity. We treated water hyacinth plants with maximum label (Florida, USA) rates, of diquat, glyphosate, and 2,4-dicholorphenoxyacetic acid in three experiments, combining treated water hyacinth with soil and planting a tomato seedling in the mix to assay for residual herbicide effects. Statistically significant reductions in tomato plant biomass, and mortality, were found for as long as seven days after herbicide application with 2-4,D and 14 days with glyphosate.

DRAWDOWNS TO CONTROL HYDRILLA: THE LAKE MURRAY EXPERIENCE. Steven J. de Kozlowski and Cindy Aulbach-Smith, South Carolina Department of Natural Resources, Columbia, SC

Lake Murray is a 50,000 acre multipurpose impoundment located near Columbia, South Carolina. Dioecious hydrilla was first observed in the lake in 1993 and quickly expanded to cover over 3,000 acres by 1995. In 1996, an integrated management strategy was implemented combining a 15-foot drawdown with herbicide applications to control hydrilla. Surveys the following year indicated an 88% decrease in hydrilla while seed producing aquatics flourished. Hydrilla treatments in 1997 amounted to only 176 acres. Details of the drawdown, herbicide treatments and results will be discussed.

OVERVIEW OF AQUATIC PLANT MANAGEMENT IN WASHINGTON STATE. Kathy Hamel, Washington Department of Ecology, Olympia, WA 98504-7600.

The main problem aquatic species in Washington are *Hydrilla verticillata, Myriophyllum spicatum, M. aquaticum*, and *Egeria densa*. Working in partnership with local governments and lake residents, Washington Department of Ecology staff are exploring ways to eradicate or contain populations of these plants. Using techniques developed by Waterways Experiment Station, we have had some success in eliminating milfoil from a number of lakes. We are working towards hydrilla eradication at our only site in Washington. An update will be presented about these and other aquatic plant control efforts that are underway in Washington.

FUSARIUM SP. AS A POTENTIAL BIOCONTROL AGENT OF *EGERIA DENSA* AND *EGERIA NAJAS* IN BRAZIL. G. F. Nachtigal, R. A. Pitelli, and N. Gimenes F., Faculty of Agricultural and Veterinary Sciences, University of the State of Sao Paulo (UNESP), Jaboticabal, SP Brazil.

Egeria densa and *Egeria najas* are two troublesome submerged weeds in Brazillian hydro-power reservoirs, affecting mainly energy production and turbine durability. Chemical and mechanical controls are not feasible due to the cost and the great depths of the lakes. Biocontrol is a possible tool to manage these weeds. Accordingly, several trips were made to various swamps and rivers in Brazil to collect fungi, bacteria, and insects that attack *Egeria* spp. After initial laboratory studies, a *Fusarium* sp. was selected which severely damaged both weed species, especially *E. densa*. In laboratory tests, the symptoms were stem necrosis and chlorosis, beginning at the base and extending to the tip of the stem, and complete plant

disintegration due to the loss of tissue integrity. Chlorosis and complete plant collapse occurred at a concentration of 4 x 10^4 conidia ml^{-1} (ranged tested: 8x10^3 to 1 x 10^6 conidia ml^{-1}). The surviving plants grew poorly. Various low-cost solid media (corn, rice, wheat grains, and sunflower seeds) were tested for production, drying, and manipulation of inoculum. The inoculum produced on corn, rice, and wheat had the same high level of infectivity on the two weeds, but the inoculum produced on sunflower was less infective. Considering inoculum yield and ease of drying and manipulation, rice was chosen for inoculum production. When the fungus was applied at 0.1, 0.3, 0.7, and 1.0 g L^{-1} of dry, ground, infested grains, maximum levels of infection occurred at the rates of 0.7 and 1.0 g L^{-1}, four days after inoculation. This inoculum remained viable and infective for 8 months at 4 °C.

AQUATIC VEGETATION OF THE RIO PARANA, BRAZIL: A FUNCTIONAL ASSESSMENT. K. J. Murphy1, S. M. Thomaz[2], and L. M. Bini[3], [1]Division of Environmental and Evolutionary Biology, University of Glasgow, Glasgow, Scotland, [2]NUPELIA, Universidade Estadual de Maringa, Maringa, Brazil, [3]Universidade Federal de Goias, Goiania, Brazil.

We report the initial results of a functional analysis of the macrophyte vegetation of the river channel and its associated *varzea* (floodplain) wetland waterbodies within the last remaining unregulated stretch of the Rio Parana in southern Brazil. Data on a range of morphological measures of the aquatic macrophyte species present at target sites within the system were analyzed and related to water physico-chemistry variables, in a preliminary assessment of the functional characteristics of the major aquatic vegetation types present within the system. The results may be of particular interest to aquatic plant managers because many of the native dominant species of the system (e.g. *Eichhornia crassipes, Egeria densa, Salvinia auriculata, Myriophyllum aquaticum*) are significant aquatic weed species elsewhere in the world.

CAN *EGERIA DENSA* BE ERADICATED? ANSWER: YES, BUT IS IT WORTH IT? Lars W. J. Anderson, USDA-ARS, Aquatic Weed Research Laboratory, Davis, CA 95616.

Egeria densa, a native to South America, has increased its distribution and adverse impacts in several western states over the past decade. California has recently initiated a million-dollar per year management program to reduce biomass and associated problems caused by this submersed weed in the Sacramento-San Joaquin Delta. Habitats in California and other states range from extremely fast-moving, tidally-influenced waters in the Delta to more quiescent lakes and reservoirs. Although this plant has physiological attributes that allow it to invade and spread (e.g. low light compensation point, anchorage in flowing water, dense upper canopy formation, and facile vegetative reproduction through fragments), it does not form seed or any other long-lived perennating structures such as turions or tubers. *Egeria*'s "overwintering" success and spread seems to derive from its ability to allocate sufficient carbohydrate reserves in its rhizomes in fall, coupled with fragment dispersal all season. Thus, judicious timing of herbicide application (contact and systemic), prevention of dispersal (via fragment drift and recreation activity), and a well-focused public education program could gradually reduce populations to zero in some locations. The key to eradication is the prevention of reinfestation. Since this plant cannot sustain itself without adequate top-growth, eradication may be attainable if re-introductions are halted. The short-term costs of an intense, expensive eradication approach should be weighted against the very long-term costs of "management" that continues indefinitely. From an environmental standpoint, there may be far less negative impacts from both *Egeria* and long-term management methods if eradication is chosen.

THE ALGICIDE TOLERANCE OF FILAMENTOUS ALGAE. Carole A. Lembi, Department of Botany and Plant Pathology, Purdue University, West Lafayette, IN 47907.

Field observations strongly suggest that filamentous mat-forming algae vary in their susceptibility to standard algicide applications, most of which contain copper. For example, *Spirogyra* is considered to be more susceptible to copper than *Cladophora* or *Pithophora*. Reasons for this variability can range from internal factors (e.g. genetic makeup, cell wall composition) to external factors (e.g. growth habit of the mat, propensity for the cells to be coated with sediment, other algae, etc.). To separate these factors, we conducted copper dose response studies with several filamentous algae in unialgal culture, so that external factors were reduced. *Pithophora* and *Hydrodictyon* were more tolerant of copper than *Spirogyra*. A "new" problem algal to our region, the blue-green (cyanobacterial) *Oscillatoria*, was also tested. The *Oscillatoria*

infestations appear to be multi-species in nature, and these species vary in their tolerance to copper. At least one *Oscillatoria* species appears to be virtually untouched by copper even at the highest permissible doses. This internal tolerance plus added external factors such as clinging sediment, diatoms, and slime from both diatoms and *Oscillatoria* may account for the difficulties that applicators are having with *Oscillatoria* control.

APMS 1999

Asheville, North Carolina

Downtown Asheville is one of those rare cities where you feel comfortable walking around, and for more than one reason. With one of the best collections of art deco architecture in the country, antique stores galore, art galleries and boutiques, and a diverse selection of downtowners, you'll never want to leave. Asheville has a downtown with a broad character and its architecture sets a romantic European mood that you want find the likes of anywhere else in the state. The sparkling, stylized details found in Asheville's early art deco and gothic buildings echo the pre-depression heyday of the 1920's. While enjoying the views and architecture in downtown Asheville don't forget to visit one of the 100 retail shops where you can buy local goods and crafts as well as unique treasures from around the world. Both moderate and upscale restaurants can be found throughout downtown offering every kind of cuisine imaginable from Italian and Cajun to vegetarian. Those who prefer the outdoor cafe or coffeehouse setting will also find themselves at home at the many cafes spread throughout downtown, each with its own particular brand of local art, music and charm.

There is something to do every day of the week in downtown Asheville. Visit the home of one of Asheville's famous sons, writer Thomas Wolfe, or browse through an art gallery on Biltmore Avenue. Have a look inside the historic St. Lawrence Basilica with one of the few self-supporting domes in the country - the doors are always open. Or, have an espresso and watch the city pass by until evening falls. Then head down to the Community Theater or Diana Wortham Theater for a play, a symphony or a modern dance performance. If you're into old time blues or rock n' roll check out one of downtown's many clubs or bars. Don't forget the Craft Fair or the poetry reading at the bookstore.

The people are friendly. Entangled in the diversity of architecture are Asheville's people, from artists and musicians to corporate executives, merchants and entrepreneurs. Even an occasional panhandler. Some say that parking can be a problem, but a few quarters in a parking meter and a short walk to a secure parking deck is a small price to pay for a city made of stone, marble, granite, reaching towards the sky.

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