ABSTRACTS

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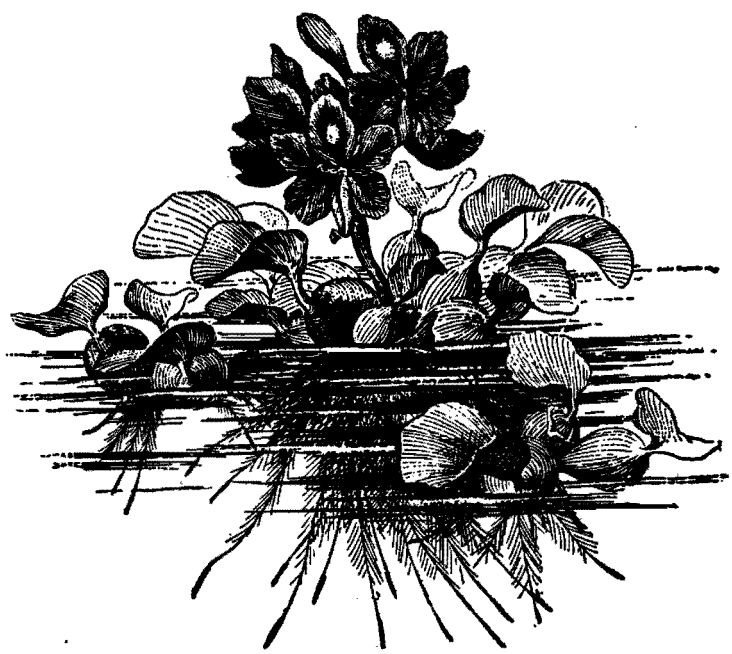
AND MANAGEMENT OF AQUATIC PLANTS



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NOTE

The numbers accompanying the abstracts correspond to the paper titles in the program. The abstracts have been reviewed and standardized by the Editorial Committee. The Committee did not intend to change the meanings of the abstracts, and we apologize if this inadvertent error has occurred. The alternate abstracts (>146) are substitute papers when cancellations occur in the program after printing. The Program and Editorial Committees wish to express their appreciation to Patti Mikel and Bobbi Goodwin for typing the abstracts. Alison Fox formatted and provided camera-ready copies of the program, and Jan Miller volunteered similar duties for the abstracts.

Clarke Hudson and Bill Haller.

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1 AQUATIC WEEDS IN DEVELOPING REGIONS

T. Petr, Food and Agriculture Organization, Fisheries Department, (FIRI) 00100 Rome, Italy

In spite of their preference for high dissolved nutrient concentrations in water, Salvinia molesta and Eichhornia crassipes are known to undergo an explosive growth in "clean" waters. In the 1950's, water hyacinth invaded a large swamp area of the White Nile called the 'sudd' in Sudan, and from there it spread downstream to the Nile. It now forms not only a formidable obstacle to water transport in the sudd, but also blocks numerous irrigation canals and drains in Lower Egypt. In the 1960's Salvinia molesta covered much of the surface area of the new Kariba reservoir on the Zambezi River, and in the early 1980's the same weed spread over more than 200 km^2 of floodplain lakes and oxbows of the Sepik River in Papua New Guinea. Both salvinia and water hyacinth have now spread through the African continent, tropical and sub-tropical Asia, and some of the islands of the Pacific. Sustainable control of both plants is on the list of priorities of many governments and FAO and other agencies and institutions have been assisting with development of management and control strategies. FAO collaborates in the preparation of rational aquatic plant management programmes in irrigation and drainage schemes, and in floodplain, reservoir, and lake management for safeguarding the requirements of agriculture and fisheries. FAO has also been looking into the benefits of such plants for fish stocks in inland waters and their use in aquaculture.

2 THE ECOPHYSIOLOGY OF AQUATIC PLANTS

George Bowes, Department of Botany and Center for Aquatic Plants, University of Florida, Gainesville, Florida 32611, USA.

Terrestrial plants possess many adaptations that enable them to cope with the potential bane of their existence: limited water supplies. Aquatic plants, on the other hand, face the opposite dilemma: an environment with too much water. This fact has important implications, both direct and indirect, in terms of their ecophysiology. The density of water has a major influence on the morphology and anatomy of submersed plants. Furthermore, an aquatic plant may have to exist in an environment of potentially unfavorable pH and solute concentrations, because water is a polar solvent which bathes the shoots as well as roots of submersed plants. Water may severely limit access to light, inorganic carbon, and oxygen. Conversely, in some situations the diffusion resistance of water may result in deleteriously high oxygen concentrations. As a consequence, aquatic plants show somewhat unique morphological, anatomical, physiological, biochemical, and possibly molecular adaptations, which improve their ability to survive and gain access to the essential components for growth and reproduction, in an environment which may exert more stresses than many terrestrial systems. This paper will address some of the unusual adaptations in aquatic species, especially with regard to photosynthesis, and how these may influence their weed status.

Supported in part by Grant No. 91-373-06-60000 from the USDA National Research Initiatives Competitive Grants Photosynthesis Program, and by Contract No. C-7307 from the Florida Department of Natural Resources.

3 ENVIRONMENTAL PROBLEMS IN POST-COMMUNIST CENTRAL EUROPE

J. Kvet, Czechoslovak Academy of Sciences, Institute of Botany, Dukelska 145, CS-37982 Trebon, Czechoslovakia.

The Central European "new democracies" are confronted with a serious ecological crisis. Its symptoms are, among others, high levels of pollution, eutrophication and reduction of biodiversity. The reasons for this ecological crisis are primarily economic and the main clues to its stepwise solution are: a) strict environmental legislation, b) reduction of energy use per unit GNP, and c) environment-friendly technologies. While the adoption of a) is progressing well, its implementation depends on b) and c), whose introduction is impeded by lack of funds. Significant progress can only be achieved with a substantial help from abroad.

The high water pollution and eutrophication in Central Europe comes from numerous: 1) point sources due to a) insufficient numbers of water treatment plants, performing mostly only secondary treatment, and b) practical absence of tertiary treatment; and 2) non-point sources, mostly due to persisting prevalence of farming practices enhancing soil deterioration and erosion, mineralization of humus and leaching of mineral nutrients, a high proportion of which ends up in surface or ground water.

In all these instances, the introduction of measures for water-quality protection employing aquatic and marsh plants is justified, but various constraints on their use must be respected. The use and management of certain higher plants for water-quality control in Central Europe will be discussed.

4 ECOLOGY AND MANAGEMENT OF SUBMERGED AQUATIC WEEDS

Clive Howard-Williams, Taupo Research Laboratory, National Institute of Water and Atmosphere Research, Box 415, Taupo, New Zealand.

Aquatic weed problems in New Zealand are caused by introduced submerged species, particularly those of the family Hydrocharitaceae. These have successfully outcompeted the native flora in depth range 1 - 6 m and spectacular invasions are still occurring. Their growth is particularly marked in clear oligotrophic lakes where biomass values of up to 8000 g m^{-2} (dry mass) have been recorded. In lakes at latitudes less than 40° S, year around growth of aquatic weeds occurs. Sediment characteristics and turbulence due to wave action appear to be the major factors controlling the variability in natural growth. Examination of the literature shows that

well planned scientific experiments on weed management strategies (with adequate experimental control) are not common. For instance, NZ data shows that natural declines in weed bed structure can occur which can complicate the interpretation of management methods. Temporal variation in the dynamics of weed bed structure shows high variability at single sites. Analyses of the long-term effects of control strategies are discussed with special reference to the use of mechanical harvesting.

5 AQUATIC PLANT MANAGEMENT-DEVELOPMENT PERSPECTIVES AND NEEDS

Tom Brabben, The World Bank, 1818 H Street NW, Washington, DC 20433.

Environmental management and the need to sustain development investments is increasing demands for alternative developments in technology. The role of the International Program for Technology Research in Irrigation and Drainage, (IPTRID) and the importance of continuing research and technology development for irrigated agriculture is given. One of the priority themes for IPTRID is to improve technologies for maintenance. Effective aquatic plant control is a major problem in most irrigation and drainage systems, especially in tropical climates. Aquatic plant management, including the control and use of vegetation, is considered in relation to development, particularly the development and sustainability of irrigation and drainage. Research needs to improve aquatic plant management in developing countries by adaptive field research, technology transfer, and training are identified and some examples of techniques that could be employed for sustainable control are given. The World Bank's experience of the use of aquatic vegetation is also considered. The use of Duckweed (Lemnaceae) for wastewater treatment and aquaculture in developing countries is given as one example. Progress to adapt the results of aquatic plant research and control technologies into practical solutions is likely to be enhanced by inter-disciplinary "networks" and closer collaboration between scientists, engineers, and managers.

6 TEN YEARS OF INFORMATION SERVICES

Victor Ramey, Center for Aquatic Plants, IFAS, University of Florida, 7922 NW 71st Street, Gainesville, Florida 32611.

Bibliographies. Reprints. AQUAPHYTE. Public education booklets. Illustrations. Student services. Educational videotapes. For ten years, the UF/IFAS Center for Aquatic Plants has built and maintained a computerized information system about aquatic plant ecology, physiology, utilization and management. The "ups" have been greater than the "downs" and we continue to show steady growth in the number and kinds of services rendered and the number of users served.

7 NONINDIGENOUS AQUATIC NUISANCE PREVENTION AND CONTROL ACT OF 1990; THE AQUATIC NUISANCE SPECIES TASK FORCE

William E. Roper, Headquarters, U.S. Army Corps of Engineers, Washington, D.C.

The Act passed in 1990 mandates development and implementation of a comprehensive national program to address problems related to unintentional introductions of nonindigineous aquatic species into waters of the United States. The program is intended to reduce the risk of such introductions and, when warranted, to control aquatic nuisance species that become established. The Act requires and authorizes the establishment of an Aquatic Nuisance Species Task Force to develop and implement the program. The task force is composed of the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration as co-chairs and members including the U.S. Environmental Protection Agency, the U.S. Coast Guard, the U.S. Army Corps of Engineers, other Federal agencies, and various ex officio members as deemed appropriate by the co-chairs. Although it specifically addresses Zebra Mussels, the Act is much broader and further affects matters of major interest to the aquatic plant management community.

8 THE LONG WATER - KISSIMMEE RIVER

Charles E. Graves, South Florida Water Management District, 1000 NE 40th Avenue, Okeechobee, Florida 34972.

The following topics will be discussed: 1) Background history of the Kissimmee River dating back to the mid-1800's, 2) Circumstances in detail concerning water traffic and flood control that lead to the channelization of the Kissimmee River, 3) Impact that channelization had on the environmental elements and aquatic plant management, 4) Prospective reasoning for possible restoration of parts or all of the Kissimmee River, including aspects from the environmental, water quality and public usage of the river, 5) The different alternatives being reviewed and studied for possible implementation, and 6) Data compiled so far on the Pool B experimental project already in place and the effects that this has had so far on the entire ecosystem of this area.

9 THE AQUATIC PLANT INDUSTRY, AN OPPORTUNITY FOR INTERNATIONAL COOPERATION

Don Bryne, Suwannee Labs, P.O. Box 1823, Lake City, Florida 32056.

Suwannee Labs, one of the largest aquatic plant nurseries in the U.S. has supplied plants for aquarists, wetland restoration, scientists, and others for over 25 years. Consumer's demand for ornamental plants and plants for constructed wetlands is a major growth area for aquatic nurseries. Nursery owners travel extensively and usually attain wide experience in plant geography, growth parameters, disease, and general plant culture. Botanists and plant suppliers in foreign countries may benefit from knowledge gained on various species, and new markets may be developed for ornamental plants.

10 PROCESS AND PROGRESS OF AQUATIC HERBICIDE RE-REGISTRATION BY THE USEPA

Fred Kerpel, U.S. Environmental Protection Agency, Pesticides Section, 345 Courtland Street, N.E., Atlanta, Georgia 30365.

EPA has many programs which have to change with the felt necessities of the times. One such program is in the Pesticide & Toxic Substances Branch, simply known as Pesticides. Operating under the act known as FIFRA, the section is charged among other things with labeling of pesticides and how this, in turn, affects ground water, worker protection, endangered species, and food safety. This presentation will report on the progress of regulations regarding each of these topics. The progress and process of re-registration of all pesticides will also be presented. Personnel will be available during the meeting at the EPA display in the exhibit room to answer questions.

11 INHIBITION OF PROPAGULE FORMATION AND PROPAGULE DORMANCY BY MARINER HERBICIDE IN HYDRILLA VERTICILLATA, POTAMOGETON NODOSUS: IMPLICATIONS FOR LONG-TERM MACROPHYTE MANAGEMENT

Lars W.J. Anderson, Stuart Perry and Angela Cains, USDA-ARS Aquatic Weed Control Research Laboratory, Botany Department, University of California, Davis, California 95616.

Inhibition of tuber and winter bud formation in hydrilla, sago pondweed and American Pondweed by bensulfuron methyl (Mariner) was first discovered at this laboratory in the late 1980's. Since the ability of noxious aquatic weeds to perennate is critical to their survival and since these propagules can be long-lived, Mariner can provide a heretofore missing tool for reducing population densities. The herbicide is active via

water at 10 to 100 ppbw, or when applied onto exposed soil at 50 to 250 g/ha, thus offering a variety of strategies for plant uptake. Recent studies here confirm that properly timed Mariner exposure can disrupt normal dormancy in newly formed propagules. This novel effect should further interfere with the normal perennation. Preliminary results indicate that stimulation of ethylene is not involved with either propagule inhibition, nor interference with dormancy.

12 HYDRILLA CONTROL TRIALS IN FLORIDA WITH MARINER® (BENSULFURON METHYL) HERBICIDE

Ken Langeland, Center for Aquatic Plants, 7922 N.W. 71st Street, Gainesville, Florida, 32606.

Mariner®, a du Pont product for aquatic vegetation management, which contains the active ingredient bensulfuronmethyl(methyl2-[[[[[(4,6-dimethoxy-pyrimidin-2-yl)amino]carbonyl]amino]sulfonyl]methyl]benzoate) was applied to four Florida lakes at different times and concentrations as follows: Johnny's lake received 25 ppb a.i. in May, June, August, and October, 1990; Catfish Lake received 100 ppb a.i. in July, 1990; Palmer Ranch Lake received 25 ppb in August, 1990 and 50 ppb in August 1991; and Lake Wastena received 40 ppb in August 1991. Hydrilla height in the water column was measured by fathometer tracings in all four lakes. Biomass was measured in Johnny's lake, Palmer Ranch Lake, and Lake Wastena. Tuber density was measured in Catfish Lake, Palmer Ranch Lake, and Lake Wastena. Hydrilla height declined in Johnny's Lake after 90 days; and biomass after 147 days. Biomass and height in Johnny's Lake became zero by 438 days and remained negligible through 469 days. Hydrilla height became negligible after 95 days in Catfish Lake and remained in this condition through 391 days, while tuber density has not changed. Hydrilla height was temporarily decreased in Palmer Ranch Lake, while biomass and tuber density did not change significantly through 347 days following the initial application. Hydrilla height decreased in Lake Wastena by 53 days after application, while biomass and tuber density did not change by 197 days.

13 USE OF HOLLOW-FIBER DIALYSIS TUBING FOR MEASUREMENT OF DIFFUSIVE FLUX OF BENSULFURON METHYL IN SEDIMENTS

Mark D. Sytsma and Lars W.J. Anderson, Department of Botany and USDA/ARS Aquatic Weed Research Laboratory, University of California, Davis, California 95616.

Growth of aquatic macrophytes is influenced by, and has an influence on, the environment. Sediment characteristics are an important determinant of macrophyte distribution and abundance; and, in turn, macrophyte growth determines sediment physical and chemical characteristics. Macrophyte growth inhibition on low-density, highly organic sediments has been attributed to the inability of these sediments to supply nutrients at a rate adequate to support growth, primarily because of low diffusive flux rates of nutrients. Diffusive flux rate is also an important consideration when herbicides are applied directly to sediments. Diffusive flux rate may influence off-site movement and availability of the compound for root uptake. We have developed a technique for measuring diffusive flux of compounds in sediments that uses hollow-fiber dialysis tubing as a root analog. The technique was used to measure diffusive flux of bensulfuron methyl in sediments that varied in clay and organic matter content. The potential of the technique for modelling pesticide and nutrient flux in sediments will be discussed.

14 EFFICACY OF BENSULFURON METHYL ON EURASIAN WATERMILFOIL

L.S. Nelson, M.D. Netherland and K.D. Getsinger, USAE, Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi 39180.

Studies were conducted to evaluate the effectiveness of bensulfuron methyl on Eurasian watermilfoil (Myriophyllum spicatum L.). Plants were grown in 55-liter aquaria under controlled-environment conditions for

three weeks prior to chemical treatment. Following a 7-, 14-, and 21-day exposure period at concentrations ranging from 10-2300 μg ai l^{-1}, plant biomass was reduced 31 to 85% compared to untreated plants. Treatments of 50, 75, 100, 125, and 150 μg ai l^{-1} at 35 and 42 days exposure resulted in shoot biomass reductions greater than 85% compared to untreated plants. Only treatments of 230 μg ai l^{-1} and higher inhibited root growth. Regrowth was observed on all treatments, indicating the potential for plant recovery. Regrowth emerged from root crowns, lateral buds along stem nodes, and apical tips, and was evident 1 to 2 weeks following removal of the bensulfuron methyl treated water. Although complete plant control was not achieved in these studies, our results suggest that an extended contact time may be more critical than chemical concentration when managing Eurasian watermilfoil with this compound.

15 SENSITIVITY OF FLOATING AQUATIC WEEDS TO IMAZAPYR IN THE WATER COLUMN

Chad R. Coley and Stratford H. Kay, North Carolina State University, Raleigh, North Carolina 27695, USA.

Duckweed (Lemna purpusilla), waterferns (Azolla caroliniana and Salvinia rotundifolia), water lettuce (Pistia stratiotes), and water hyacinths (Eichhornia crassipes) are common plants occurring in impoundments, streams, and backwater areas in the southeastern United States. The objective of this study was to determine the feasibility of using imazapyr to selectively remove water hyacinths and water lettuce from aquatic plant communities while minimizing effects on less invasive species such as duckweed and waterferns. Plants were exposed to a range of imazapyr concentrations in static culture in the greenhouse to determine their relative sensitivities to this herbicide when applied to the water column. Duckweed and both species of waterferns were severely damaged by concentrations of imazapyr less than 0.25 mg/l during a two week exposure period. Similar studies on waterhyacinths and water lettuce currently are in progress. Additional tests will determine contact time required for control and the response threshold for each species.

16 THE INFLUENCE OF CULTURAL FACTORS AND GLYPHOSATE ON THE CONTROL OF TORPEDO GRASS (PANICUM REPENS L.)

Brian E. Smith, Donn G. Shilling, University of Florida, Agronomy Department, Building 164, Gainesville, Florida 32611 and W.T. Haller, University of Florida, Center for Aquatic Plants, 7922 N.W. 71st Street, Gainesville, Florida 32606.

The influence of cultural practice and/or glyphosate on the control of torpedo grass was evaluated under both field and greenhouse conditions. In order to determine the effect of disking and glyphosate application on a natural stand of torpedo grass, studies were conducted during the draw-down at East Lake Tohopekaliga near St. Cloud, Florida in 1990. The field was first burned and then half the field was disked twice. Three rates of glyphosate, 1.13, 2.26, and 4.48 kg/ha, were applied at three physiological stages of development in both the disked and nondisked areas. To evaluate possible direct effects of disking, torpedo grass rhizomes were sectioned into 4 lengths (5, 10, 15, and 20 cm) and planted at 5 depths (0, 5, 10, 20, and 30 cm). In the field, above and below ground biomass was collected one year after treatment. Disking alone reduced above and below ground biomass by 33% and 10%, respectively. However, disking in combination with glyphosate did not improve the efficacy of glyphosate on torpedo grass. Physiological stage of development of torpedo grass did not significantly affect the efficacy of glyphosate. In the greenhouse, as rhizome section length decreased and depth increased shoot emergence declined. Current studies are being conducted to determine if disking in combination with glyphosate could potentially improve herbicide efficacy on torpedo grass.

17 EVALUATION OF MYRIOPHYLLUM SIBIRICUM IN AXENIC CULTURE AS A BIOASSAY FOR PREDICTING EFFECTS OF PESTICIDES ON NON-TARGET AQUATIC PLANTS

Roxana D. Roshon, Gerald R. Stephenson and Roger F. Horton, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

In Canada, prior to the registration of new pesticides, non-target aquatic organism testing is required. Standardized tests exist for algae and Lemna but no protocol exists for determining pesticide effects upon non-target rooted aquatic macrophytes. In an attempt to develop a suitable test, Myriophyllum sibiricum Komarov was cultured axenically. Pesticides with varying modes of phytotoxic action, including 2,4-D, atrazine, amitrole, glyphosate, chlorsulfuron, trifluralin, and propaconazol were tested at concentrations between $1x10^{-4}$ and $1x10^{-6}$ M. Based upon shoot and root growth, development of chlorosis and fresh and dry weight values, preliminary data suggest that this test may be a simple, rapid, inexpensive and reproducible bioassay of the effects of pesticides upon a non-target aquatic plant.

18 COPPER RESIDUES IN THE ENVIRONMENT - WHAT ARE WE LOOKING FOR?

Edwin F. Koldenhoven, Griffin Corporation, P.O. Box 1847, Valdosta, Georgia 31601.

Copper is an essential element for human health and an important part of human civilization. Copper has had a wide range of medicinal, industrial, military, and agricultural uses for more than 5,000 years. The use of copper to control algae and aquatic weeds has raised many questions as to what happens to copper after it has performed its desired function. Since elemental copper does not decompose, does it then accumulate in the environment and pose problems for future generations, or does ionic copper (the only toxic form) form complexes with other molecules in the environment rendering it harmless, or biologically unavailable? The above questions need to be answered using scientific principles rather than public opinion. The fate of copper in the environment needs to be determined on the basis of which copper species are present and if those copper species are bioavailable.

19 SEASONAL VARIATION IN PHOTOSYNTHETIC CAPACITY OF EELGRASS LEAVES IN RELATION TO LEAF AGE, CHLOROPHYLL a AND NUTRIENT CONTENT

Jens Borum, Freshwater-Biological Laboratory, University of Copenhagen, Denmark.

Photosynthesis-light relationships of individual eelgrass leaves, measured in different seasons but at a constant temperature, were compared using leaf age, chlorophyll a and tissue-bound nutrient content. The objectives were to describe seasonal changes in the photosynthetic capacity in relation to changes in light climate and temperature, to establish possible "critical" nutrient levels for photosynthetic capacity of eelgrass leaves, and to examine whether re-allocation of nutrients within the plant is accompanied by a decrease in photosynthesis.

Chlorophyll a, photosynthetic efficiency at low light, and maximum photosynthesis at saturating light were high throughout the winter period and tended to compensate for low in situ light and temperature. Nitrogen, phosphorus, and chlorophyll a decreased with increasing leaf age and so did rates of respiration, photosynthetic efficiency, and P_{max}. Variations in chlorophyll a and P_{max} suggested a "critical" nitrogen level of 2% of dry weight. Re-allocation of nitrogen from old to young leaves is accompanied by a reduction in photosynthetic capacity of the source tissue throughout the summer period, when concentrations of tissue-bound nutrients are low.

20 CHLOROPHYLL FLUORESCENCE OF POTAMOGETON LUCENS AND ELODEA CANADENSIS: THE RESPONSE OF PHOTOSYNTHETIC ELECTRON TRANSPORT TO LIMITING CO_2 CONCENTRATIONS

Lucina C. van Ginkel, Philip R. van Hasselt and Hidde B.A. Prins, Biological Center RUG, Laboratory of Plant Pathology, ECOTRANS, P.O. Box 14, 9750 AA Haren, The Netherlands.

In submerged aquatic macrophytes photosynthesis and growth are often limited by the availability of inorganic carbon. Several species have developed strategies, often CO_2 concentrating mechanisms, to overcome this limitation. Elodea canadensis can use bicarbonate as a carbon source for photosynthesis. This species contains extracellular carbonic anhydrase and uses a so called polar proton transport system to convert extracellular HCO_3^- into CO_2 by acidification of the apoplast of the lower epidermis. Elzenga, 1989[1], showed that this process of bicarbonate utilization is regulated by the ratio between light and CO_2 available for photosynthesis. It was proposed that the balance between light and CO_2 changes the ratio of NAD(P)H/NAD(P) in chloroplast and cytoplasm, and that this ratio in turn regulates the plasmamembrane bound ATPase which drives the polar transport system. Using chlorophyll fluorescence measurement techniques we have found that available CO_2 in Elodea canadensis has an effect on the photosynthetic electron transport, indicating that the availability of CO_2 in the chloroplast directs the generation of reducing power.

[1] Elzenga, JTM & Prins, HBA, 1989, Plant Physiol 91, 68-72.

21 MORPHOLOGICAL AND PHOTOSYNTHETIC CHARACTERISTICS OF POTAMOGETON OBTUSIFOLIUS MERT. & KOCH, GROWN AT DIFFERENT DEPTHS

S.C. Maberly, Institute of Freshwater Ecology, Windermere Laboratory, Far Sawrey, Ambleside, Cumbria LA22 0LP U.K.

The morphological and photosynthetic response to P. obtusifolius grown at depths between 0.5 m (50-64% surface light), and the depth limit of 3.6 m (3-5% surface light) were determined in order to assess their contribution to survival at low light. Specific leaf area increased with depth. Shoot height varied 5-fold over the depth range. Plants at 3.6 m produced a given height of shoot with nearly 7 times less dry weight than shoots at 0.5 m. Shoot dry weight varied 14 fold over the depth range with a minimum weight at 3.6 m which was little different from turion weight. Seed heads were not produced on plants rooted at 3.5 or 3.6 m, and no side shoots were produced at 3.6 m so plants growing at the depth limit may derive from turions produced in shallower water. At saturating concentrations of inorganic carbon, V_{max} per unit dry weight and I_K decreased, and the apparent photon yield increased with depth. The possible effects of the photosynthetic and morphological characteristics were determined by modelling the light climate at different depths.

22 PHYSIOLOGICAL PLASTICITY IN ELODEA NUTTALLII (PLANCH.) ST. JOHN

J.I. Jones, J.W. Eaton and K. Hardwick, School of Life Sciences, University of Liverpool, Liverpool, L69-3BX, ENGLAND.

Elodea nuttallii, a problem weed in Britain, has been found to adapt rapidly to conditions of high pH and low CO_2, conditions which are normally associated with low growth rates. This adaptation has consequences with respect to modelling plant growth and predicting weed problems in the field. Investigations indicate that E. nuttallii is able to utilize bicarbonate by active transport, pumping H^+ to the lower leaf surface and OH^- to the upper surface, as proposed by Prins et al (1982, Plant Cell Environ. 5:207-14). For much of the time this mechanism does not operate in the field, but laboratory experiments have shown that it is rapidly switched on, over a very small pH range, as carbon dioxide supply becomes limiting. Evidence is presented that bicarbonate

uptake does occur in the field and its significance to the plant's growth discussed. These results are compared with physiological plasticity in the closely related Elodea canadensis.

23 INORGANIC CARBON TRANSPORT AND THE INTERNAL LIMITING FACTOR FOR PHOTOSYNTHETIC PRODUCTION IN SUBMERGED MACROPHYTES

Sven Beer, Department of Botany, Tel Aviv University, Tel Aviv 69978, Israel.

When comparing the CO_2-affinity of the primary carbon fixing enzyme in marine macrophytes (Rubisco) with seawater CO_2 concentrations, it becomes apparent that these plants would need a CO_2 concentrating system in order to photosynthesize and grow at appreciable rates. Using the efficient photosynthesizer Ulva, we have shown that HCO_3^- uptake is the first step in such a system, and that this brings about increased internal CO_2 concentrations which could saturate carboxylation via Rubisco and alleviate its oxygenase activity[1]. The mechanism of HCO_3^- uptake is not yet fully understood but seems, at least in Ulva, to utilize a transport protein featuring characteristics similar to that of an mammalian red blood cell anion transporter[2]. It is postulated that this protein could facilitate HCO_3^- transport in marine macroalgae to the extent that inorganic carbon uptake per se would not constitute a limiting factor for photosynthesis, but rather that the Rubisco activity could regulate their photosynthetic performance. This is supported by findings that Rubisco carboxylating rates correlated with photosynthetic rates in several marine macrophytes (but not in freshwater ones) and that the two rates were close to unity[3]. It is thus tentatively suggested that the carboxylase activity of Rubisco may be the internal limiting factor for marine macrophyte photosynthetic production while the inorganic carbon transport system into the cells may be the limiting factor for submerged freshwater macrophytes.

[1] Beer, Israel, Drechsler & Cohen, Plant Physiol. 94: 1542-1546, 1990; [2] Drechsler & Beer, Plant Physiol. 97: 1439-1444, 1991; [3] Beer, Sand-Jensen, Vindbaek Madsen and Nielsen, Oecologia 87:429-434, 1991.

24 INORGANIC CARBON CONSTRAINTS ON GROWTH OF SUBMERGED MACROPHYTES

Tom Vindbaek Madsen and Mette Vadstrup, Department of Plant Ecology, Aarhus University, Nordlandsvej 68, DK-8240 Risskov, Denmark.

Inorganic carbon has long been known to be an important regulating factor for photosynthesis in aquatic macrophytes. However, the evidence of inorganic carbon in regulating growth under natural conditions is surprisingly scarce. Circumstantial evidences indicate that carbon availability may comprise a severe constraint. These include the widespread ability of aquatic macrophytes to utilize alternative sources of inorganic carbon i.e. HCO_3^--use, use of sediment CO_2, access to atmospheric CO_2 through development of aerial or floating leaves.

This paper presents data from recent studies on the effect of DIC enrichment on growth of the submerged macrophytes Elodea canadensis and Callitriche cophocarpa. The plants were grown under natural conditions in lakes with back-ground concentrations of inorganic carbon between 0.3 mM and 1 mM. The DIC enrichment was established in small enclosures open to the bulk water of the lake, but sealed from the atmosphere. The study showed that DIC enrichment was a prerequisite for the survival of Callitriche cophocarpa. The growth of Elodea canadensis was stimulated by up to 80%. The highest response was obtained by CO_2 enrichment, but also increased HCO_3^- stimulated growth. In addition, the photosynthetic performance of the plants changed in response to DIC enrichment. This result indicates that the plants tended to grow tissue with a photosynthetic apparatus which was commensurate with the resources available to them.

25 WHAT INDUCES HYDRILLA TO SHIFT BETWEEN C_3- AND C_4-LIKE PHOTOSYNTHESIS?

J.B. Reiskind, M.R. Rattray and G. Bowes, Department of Botany and Center for Aquatic Plants, University of Florida, Gainesville, Florida 32611.

It is well documented that Hydrilla verticillata can alter its photosynthetic metabolism from C_3-like under winter conditions to C_4-like under summer conditions. We have found that Hydrilla in the C_4-like state can raise its internal inorganic carbon (C_i) concentration, and thereby mitigate the deleterious effects of photorespiration in a stressful high O_2/low CO_2 environment. Several environmental factors, including photoperiod and temperature, have been associated with the induction of the different photosynthetic states and the C_i pump capacity. However, our hypothesis is that these play a secondary role, with the primary factor being the dissolved CO_2 concentration in the bathing medium. We have recorded under laboratory conditions that C_i stress can induce the shift between C_3- and C_4-like photosynthesis. Low CO_2 (below air equilibrium) decreases the CO_2 compensation point and the O_2 inhibition of photosynthesis, and increases phosphoenolpyruvate carboxylase activity. High CO_2 reverses these effects. Experiments are in progress to determine how pH and bicarbonate concentration may interact in this photosynthetic shift.

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26 ECOLOGICAL SIGNIFICANCE OF C_4-LIKE PHOTOSYNTHESIS IN HYDRILLA

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The contribution of facultative C_4-like photosynthesis to Hydrilla verticillata's success as a submersed aquatic weed has not been demonstrated. A combined laboratory and field physiological study of Hydrilla populations in Florida was designed to investigate spatial and seasonal patterns in photosynthetic physiology and environmental quality, the contribution of C_4-like photosynthesis to fitness, and the dependence of induction of C_4-like photosynthesis on plant density. Steep horizontal gradients in pH, CO_2, HCO_3^-, and dissolved O_2 were observed across a population of Hydrilla in the field. Distinct mat and edge micro-habitats were identified. The mat habitat exhibited higher plant biomass, midday depletion of CO_2 and HCO_3^- and supersaturation of dissolved O_2 or depletion of CO_2. C_4-like plants were observed from the mat and never from the edge. A reciprocal transplant experiment demonstrated that C_4-like photosynthesis enhanced productivity only in the mat habitat. Mat and edge plants performed equally well in the edge habitat. The higher nitrogen-use efficiency of the mat plants may explain the facultative nature of C_4-like photosynthesis in Hydrilla. Induction of C_4-like photosynthesis was dependent upon plant density and mediated by a reduction in resource availability and environmental quality. We conclude that facultative C_4-like photosynthesis enhances productivity under resource depletion but does not contribute to the displacement of indigenous vegetation.

27 YIELD AND NUTRITIVE VALUE OF LEAF PROTEIN OF AQUATIC WEEDS FROM NORTH INDIA

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Leaf protein concentrates have been isolated from forty-eight species of aquatic and semi-aquatic weeds from North India. Total N, protein N and antioxidant contents of leaf samples and LPC as well as percent extract of total N, protein N and protein have been determined. In addition in vitro enzymatic digestibilities of the protein concentrates were also investigated.

28 THE USE OF DRY WATER HYACINTH (EICHHORNIA CRASSIPES (MART.) SOLMS) AS A SUBSTRATUM FOR GROWING PLANTS ON THE RAFT

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This work is part of an attempt to control water hyacinth, which is a noxious weed in Thailand by utilization. A raft was made of 1 x 1 m^2 bamboo using 40 kg. of dry whole plant water hyacinth as a substratum above a cover of PV net for growing plants. Various herbaceous plants, notably tomato (Lycopersicum esculentum) and chinese cabbage (Brassica chinensis) could grow very well from seeds on this water hyacinth raft. The water hyacinth raft was found to be very productive either in flowing streams or floating along with water hyacinth growing naturally in an enclosed pond. It is advantageous that plants growing on the water hyacinth raft need no fertilizer or watering being naturally self-fed. The water hyacinth substratum lasted ca. 3 months and after harvesting the remainder was further used as a fertilizer for land plants. The raft offers a way of water hyacinth weed control and provides an economical, sustainable agriculture, alternative for plant growing in tropical countries.

29 EFFECTS OF AQUATIC PLANTS ON THE ENVIRONMENT: THE USE OF WATER HYACINTHS AND OTHER AQUATIC PLANTS FOR NUTRIENT REDUCTION IN LAKES

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Aquatic plants are a significant component of lakes which can alter and modify chemical, physical, and biological ecosystem components. The removal of aquatic macrophytes by various management strategies such as mechanical harvesting, herbicide treatment, and drawdown, have differing effects on ecosystems. The purpose of this study was to first examine the effects of these various management strategies on lake water quality and trophic state, and second to examine via a demonstration project the potential for a program integrating mechanical harvesting and the management of aquatic plant growth as a means for nutrient reduction and trophic state improvement in lakes.

It is clear from a review of the literature that mechanical harvesting is the best aquatic plant management approach from a nutrient reduction standpoint. Aquatic plants have been used for nutrient removal in numerous sewage treatment systems. The application of this technology to natural systems was examined in a demonstration project on Round Lake, a hypereutrophic 8-acre lake in Orange County, Florida. Water hyacinths (Eichhornia crassipes (Mart.) Solms) were grown in Round Lake and periodically harvested for the purpose of improving water quality. Results from the study showed large improvements in water clarity (>600%) and chlorophyll a concentrations (>90% reduction) in both the water hyacinths covered and open water halves of the lake. Nutrient concentrations in the lake declined over the study period. Harvesting of water hyacinths removed nutrients from the system which were originally present in algal biomass. These results suggest that the managed growth and harvesting of aquatic plants can be utilized for water quality improvement in lakes, but only if the plants are mechanically removed from the system.

30 NUTRIENT REMOVAL POTENTIAL OF SEVERAL AQUATIC WEEDS

Yoko Oki and Akihide Fushimi, Faculty of Agriculture, Okayama University, Okayama 700, Japan.

A small-scale pilot study to investigate the use of aquatic weeds in removing nutrients from domestic sewage was established jointly at the Prefectural Purlib Health Center, and town office and Okayama University, Okayama, Japan. From this investigation, it was evident that there was significant removal of nutrients from

wastewater all year, occurring even in winter because of polyculture which combined several emergent with submerged species.

Accordingly nitrogen uptake of several aquatic weeds used in wastewater treatment was examined during a 96-hour exposure to NH_4NO_3 solution. As a result, Scirpus fluviatilis and Juncus effusus exhibited a preferential uptake of NH_4^+ over NO_3^-, when both ions were present at equal concentrations in the same nutrient solution. In the case of Iris pseudacorus, NH_4^+ was absorbed preferentially during the first specific period and followed by the uptake of NO_3^- due to the reduction of NH_4^+.

31 LEAF PROTEIN CONCENTRATE FROM WATER HYACINTH (EICHHORNIA CRASSIPES (MART.) SOLMS)

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The leaf protein from water hyacinth was extracted in comparison with other 17 aquatic weeds in Thailand. The water hyacinth leaves yielded 23% protein while the morning glory yielded 29% and the water chestnut yielded only 4% protein. The water extraction of the leaves at pH 8.5 was found to be suitable for water hyacinth. The extracted protein from water hyacinth was further processed into the Leaf Protein Concentrate (LPC) by using acid and thermal precipitation at pH 4.0 and 82°C. The precipitated LPC was rinsed with ethyl alcohol and dried at 60°C. Chemical analysis of the water hyacinth LPC indicated 55.39% protein, 3.8% fatty acids, 0.97% fiber, 5.02% ash, and 35.54% carbohydrate. The protein fraction contained all essential amino acids and was particularly rich in Leucine (5.06%) and Phenylalanine (3.39%). The amount of these amino acids exceeds the FAO dietary allowance for daily human consumption. Thus, suggesting the water hyacinth LPC as a good source for protein in food.

33 CONTROL AND UTILIZATION OF CATTAIL (TYPHA LATIFOLIA L.)

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Three dosages of the combination of glufosinate-ammonium and imazapyr were applied in a field experiment to compare efficacy to glyphosate and imazapyr for control of cattail in irrigation systems in Thailand. Glufosinate-ammonium and imazapyr gave quick knock down activity and more comparable activity than either glyphosate or imazapyr alone. The combination of herbicides showed good control of cattail within 7 days after application. The glufosinate-ammonium and imazapyr 0.48 + 0.30 kg. ai./ha was found to be as effective a control of cattail as imazapyr 1.5 kg ae./ha in 6 months after application.

An experiment was conducted in Sakol-Nakorn province to treat municipal wastewater. The wastewater was percolated into a constructed wetland planted with cattail, an aerated lagoon, and an aerobic pond. The cattail bed, planted using 3 month old rhizome sections, showed that the removal efficiencies for BOD, COD, total phosphorus, total nitrogen and suspended solids were 39%, 31%, 35%, 25% and 68% respectively. While the removal efficiencies in the whole system were 61%, 72%, 70%, 60% and 62% respectively.

34 INJECTION OF NUTRIENTS INTO A SAND ROOTING MEDIA FOR CULTURE OF DIOECIOUS HYDRILLA

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Growth studies with dioecious hydrilla (Hydrilla verticillata (L.f.) Royle) were conducted out-doors in concrete tanks filled with flowing pond water. Nutrients were supplied to the hydrilla root zone by injecting Hoagland's nutrient solution from the surface of the water through tubing connected to an air diffuser

constructed of silica glass centrally placed in a culture container (dimensions of 20 cm in diameter by 20 cm in height) filled with sand. Each culture container was surrounded with large mesh plastic netting and window screening to form a water column 80 cm in height and 380 cm^2 in surface area which enclosed growing hydrilla plants. Screening was of sufficient size to enclose each culture container with no excess space. Sprouted hydrilla tubers were allowed to grow for 8 weeks, and one twenty-fourth of the total amount of nutrients was injected three times each week on Monday, Wednesday, and Friday during each culture period. High amounts of nitrogen, 62,500 μg per injection, severely reduced growth of hydrilla but growth improved with reduced amounts of nitrogen. This study shows the potential of this injection system to evaluate various nutrients or other chemicals placed in the root zone on growth of hydrilla.

35 INTERRELATIONSHIPS BETWEEN ROOTING DEPTHS OF SUBMERSED MACROPHYTES AND SEDIMENT NUTRIENT AVAILABILITY

Dwilette G. McFarland and John W. Barko, USAE, Waterways Experiment Station, Environmental Laboratory, Vicksburg, Mississippi 39180.

In controlled greenhouse investigations, changes in sediment nitrogen (N) profiles were examined relative to rooting depths of hydrilla (Hydrilla verticillata (L.f.) Royle) and Eurasian watermilfoil (Myriophyllum spicatum L.). Each species was grown separately on fine-textured, inorganic sediment, either amended with ammonium chloride (N-amended), or rendered infertile due to previous support of submersed macrophyte growth (unamended). For both species, diminished biomass production and increased rooting depths (down to about 60 cm) were demonstrated on infertile sediment. In N-amended sediment, significant reductions in exchangeable N concentrations occurred within 25-cm rooting depths of each species. However, in unamended sediment, N-depletion extended deeper along rooting depths of Hydrilla (approx. 55 cm) than Myriophyllum (approx. 45 cm). The results suggest that the abilities of different macrophyte species to access nutrients in sediment to adjust to marked reductions in sediment nutrient supplies may influence competitive relationships in littoral environments.

36 THE ROLE OF HYDROSOIL IN RECOLONIZATION OF NATIVE MACROPHYTES

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Establishment of balanced populations of emergent aquatic macrophytes after treatment of nuisance aquatic macrophytes requires understanding of their compatibility with prevailing hydrosoil conditions at a specific site. Eight species of emergent aquatic macrophytes (Typha latifolia, Scirpus cyperinus, Zizania aquatica, Echinochloa crusgalli, Phalaris arundinacea, Polygonum pensylvanicum, Nasturtium officinale aquaticum, and Sesbania macrocarpa) were evaluated for their potential use in revegetation of a variety of aquatic habitats. Seed germination experiments were performed to evaluate each species' potential for propagation in varying hydrosoil conditions. Further, growth under optimal hydrosoil conditions were measured. Growth and germination results indicated specificity of plants for particular hydrosoil conditions. These results should be useful for re-establishment of native aquatic macrophytes and for resolution of problems such as shoreline erosion.

37 EFFECTS OF EUTROPHICATION ON RANUNCULUS PENICILLATUS SUBSP. PSEUDOFLUITANS (SYME) S. WEBSTER AND POTAMOGETON PECTINATUS L.: AN EXPERIMENTAL STUDY

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Ranunculus penicillatus subsp. pseudofluitans plants were grown in two outdoor artificial recirculating channels, in one of which the input phosphate concentration was raised from 40 μg P l^{-1} to 200 μg P l^{-1}. The Ranunculus plants were planted in clumps, with five pots per clump, each pot containing five plants. Competitor Potamogeton pectinatus plants were planted in association with half of the Ranunculus clumps, in pots containing four Potamogeton plants. Concentrations of major elements in the water of the channels were recorded weekly. Filamentous algae grew in profusion in the channel with added P, to give a total standing crop estimated at 0.75 T fresh weight. In the other channel algae were present in negligible quantities only. Both channels were harvested after 100 days: macrophytes were removed by hand, dried and weighed, and the concentrations of major elements in plant tissues determined. Ranunculus shoot growth was poorer in eutrophic conditions, and its roots grew less well in the presence of Potamogeton. P concentrations were higher in both species in eutrophic conditions, compared with the plants from the control channel. The data are used to support the contention that Potamogeton pectinatus is the more competitive of the two species. The findings are discussed in the context of recently-reported changes in macrophyte communities in European Ranunculus streams receiving enhanced P-loadings.

38 RESPONSES OF AQUATIC AND MARSH PLANTS TO HYPEREUTROPHIC CONDITIONS IN CENTRAL EUROPEAN FISHPONDS

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In Central Europe, ancient shallow fishponds are a common type of artificial standing water bodies. Their long-lasting extensive management has now mostly evolved to a semi-intensive management. The lime, fertilizer, manure, and feed inputs and the fish stock itself, strongly modify the environment. The fishponds and their littorals may be regarded as hypereutrophic ecosystems.

Higher aquatic and marsh plants respond to these conditions by:

--increased occurrence of aquatic species capable of competing for light and mineral nutrients with dense phytoplankton and of assimilating bicarbonate in alkaline water, or escaping from this competition and stress thanks to their floating-leaved habit,

--reduced occurrence to disappearance of aquatic species unable to adapt in the aforementioned way.

--enhanced growth, production and mineral nutrient accumulation in numerous emerged or semi-emergent species, up to a certain species-dependent level of fishpond hypereutrophy. When this level is exceeded, the respective species rapidly retreats from the plant community.

Some ecophysiological mechanisms behind these plants' responses are known, but their use for control of undesirable plant species is limited by the danger of destabilization of the whole fishpond ecosystem.

39 NUTRIENT AND AQUATIC PLANT STATUS OF FRESHWATER LOCHS IN THE SHETLAND ISLANDS

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The Shetland Islands, located at approximately 60°N, 1°W, are the northernmost of the British Isles, and comprise an archipelago with complex geology and soil type. A large number of small, mainly shallow freshwater lochs are present, with very varied chemistry and aquatic vegetation. During 1991 an extensive survey of 31 lochs in Shetland was undertaken to determine relationships between water chemistry (emphasizing nutrient availability), catchment characteristics, phytoplankton standing crop, and macrophyte status. The aim was to provide baseline information relevant to assessment of the risk of eutrophication in Shetland lochs as a result of changing catchment land use. The results of a TWINSPAN analysis of loch macrophyte community data are presented. The classification is discussed in relation to data on nutrient status, catchment land use, and phytoplankton standing crop.

40 NUTRITIONAL ECOLOGY OF SUBMERSED MACROPHYTES

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Submersed aquatic macrophytes rely primarily on sediment as a direct source of nitrogen (N), phosphorus (P) and micronutrients for their nutrition. The availability of these nutrients in sediments is affected markedly by sediment type, but can also be influenced by macrophyte growth. In general, fine-textured sediments of intermediated bulk density are nutritionally superior, and support maximum growth. Results of field as well as laboratory studies have demonstrated conclusively that submersed macrophyte species, even with relatively minor root systems, can significantly deplete sediment N and P pools. From fertilization experiments involving sediments from a variety of locations, macrophyte growth on nutritionally-depleted sediments has been shown to be limited by the availability of sediment N, but not P. In aquatic systems, the vigor of submersed macrophyte beds appears to be maintained by sedimentation which provides a nutritional subsidy. Submersed macrophyte nutrition needs to be considered within the context of watershed activities and hydrologic factors that influence the seasonal dynamics of sediment transport in the littoral zone.

41 MANAGING FILAMENTOUS ALGAE GROWTH USING GRASS CARP AND ALGICIDES

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Grass carp (Ctenopharyngodon idella Val.) were stocked in a power plant reservoir for the control of filamentous algae. This resulted in a reduced need for algicide treatments and a reduction of the cost of managing filamentous algae growth in this reservoir.

42 CAPTURE OF GRASS CARP FROM VEGETATED LAKES

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Seven techniques were evaluated for catching grass carp (Ctenopharyngodon idella) in five Washington lakes containing aquatic vegetation. The methods included capturing fish with angling, pop-nets, or traps in baited areas; angling in non-baited areas; attracting fish to heated areas; and capturing fish by Asian methods which included use of lift nets and herding fish into gill nets. Herding fish into gill nets was the most effective of the techniques ($P < 0.001$), followed by angling in baited areas. Herding is effective in lakes containing thick vegetation, submerged logs and other underwater obstructions, and may be effective for removing fish from

overstocked waters, or to monitor growth.

43 PROCEDURES FOR INTRODUCING BIOCONTROL AGENTS OF NOXIOUS PLANTS INTO THE U.S.

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The introduction of agents for biocontrol of noxious plants is regulated by the United States Department of Agriculture - Animal and Plant Health Inspection Service (USDA-APHIS). Three laws address the introduction of these agents: (1) The Plant Quarantine Act of 1912, (2) The Federal Plant Pest Act of 1957, and (3) The National Environmental Policy Act of 1969. These regulations are administered by the Plant Protection and Quarantine (PPQ) Section of the USDA-APHIS. The PPQ has setup a Technical Advisory Group on Biological Control of Weeds, composed of 13 members from State and Federal agencies, which review the petition for researchers and give recommendations to the USDA-APHIS. Three types of petitions are reviewed: (1) new plant species proposed as candidates for biocontrol research, (2) requests to introduce potential biocontrol agents into quarantine, and (3) requests to field release biocontrol agents into the U.S. The process of finding, screening, and introducing biocontrol agents of weeds is lengthy, often taking 10 to 12 years before the first agent is released.

44 IMPACT OF EARLY-SEASON MIGRATIONS OF ALLIGATORWEED STEMBORERS ON ALLIGATORWEED POPULATIONS IN NORTH CAROLINA

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Alligatorweed (Alternanthera philoxeroides) persists as a serious aquatic weed problem in North Carolina. Biocontrol with insects imported from South America has not been very successful here and elsewhere in its more northerly range in the United States where the insects do not overwinter. None of three documented releases of the alligatorweed thrips (Amynothrips andersoni) or six of the alligatorweed stemborer (Vogtia malloi) and only one of nearly fifty documented releases of alligatorweed flea beetles (Agasicles hygrophila) has been successful in North Carolina. Recent field studies suggest that unsuitable climate during the summer generally prevents the establishment of beetle populations following releases. The stemborers are more tolerant of summer weather conditions than the beetles, however. Early-season migrations of stemborers in 1990 and 1991 following mild winters had a significant impact on alligatorweed populations at several locations. Data collected on mat heights at several sites suggest that the stemborers have significantly greater potential for controlling alligatorweed in its more northerly range than the flea beetles, provided that the insects are present sufficiently early in the growing season.

45 BIOLOGICAL CONTROL OF PISTIA STRATIOTES: IMPACTS OF NEOHYDRONOMUS AFFINIS AND SPODOPTERA PECTINICORNIS

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Two species of insects have been imported into the United States as biological control agents of waterlettuce (Pistia stratiotes). Neohydronomus affinis, a South American weevil, was first released in this country in April 1987. By September 1988, self-perpetuating field colonies had become established at four of the seven southern Florida waterways where N. affinis was originially released. Rapid weevil density increases (from < 250,000 to > 40 million) during the springs of 1989 and 1990 resulted in the demise of the waterlettuce populations on two of the three experimental waterways. Unfortunately, the weevils never became abundant at

the third and thus failed to control the plants. N. affinis has proven very dispersive, however, and has spread to at least 50 waterways in southern and central Florida. Waterlettuce declines have followed weevil increases at several of these sites. Because our experimental data suggested that N. affinis would probably not be universally effective, we began releasing a second waterlettuce bioagent, the Thai waterlettuce moth Spodoptera (=Namangana) pectinicornis in December 1990. Establishment self-perpetuating field colonies of this moth has proven more difficult than originally anticipated. We have therefore shifted from conducting a few small releases at numerous sites to a strategy whereby we repeatedly inoculate a single site with large numbers of S. pectinicornis over a prolonged period. We began to suspect that selective pressures inherent in long-term laboratory colonization had reduced the vigor of our cultures. To counter this, Dr. Dale Habeck recently obtained new germplasm from Dr. Banpot Napompeth in Thailand. Preliminary evidence suggests that progeny of these moths are becoming established at one field site. After we have successfully established nursery colonies at several field sites, we will begin to evaluate this insect's impact on waterlettuce populations. A literature survey indicates that there are at least a dozen other host-specific insects available for use as biological controls of waterlettuce. It is unlikely that we will need to import any of these, however. We anticipate that through the combined impacts of N. affinis and S. pectinicornis, waterlettuce will cease to be a problem weed in Florida.

46 REARING AND RELEASING HYDRELLIA PAKISTANAE AND HYDRELLIA BALCIUNASI, BIOLOGICAL CONTROL AGENTS OF HYDRILLA VERTICILLATA

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Two species of ephydrid flies, Hydrellia pakistanae and Hydrellia balciunasi, are being mass-reared at the U.S.A.E. Waterways Experiment Station. These flies are being released as biological control agents for the submersed aquatic weed, Hydrilla verticillata. In 1991, sixteen releases of H. pakistanae were made at two sites in Lake Seminole, Florida and also at one site in Lake Boeuf, Louisiana. Fifteen releases of H. balciunasi were made at one site in Sheldon Reservoir, Texas. The original overseas collection site of each species was used to select an ecologically similar U.S. release site. The insects were released as larvae into screened cages ca. 1.1 m x 1.1 m in size. The cages were placed in backwater habitats to lessen the chance of being disturbed. Release information and rearing techniques will be provided in a poster presentation.

47 EFFECT OF AUSTRALIAN INSECTS ON THE GROWTH OF THE PAPERBARK TREE, MELALEUCA QUINQUENERVIA, A SERIOUS WETLAND WEED IN FLORIDA, USA

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The growth of the paperbark tree, Melaleuca quinquenervia, in Florida is quite different from that observed in Australia, its native home. In Florida, the trees are taller, straighter, and form very dense stands. In order to determine the role which Australia's herbivorous insects may play in limiting the growth of M. quinquenervia, we initiated a sapling growth study. Sixty small (0.5 m) saplings were grown in pots beside our Townsville, Australia, shadehouse. Half of these were treated with systemic insecticides which limit (but do not entirely prevent) damage to the saplings from insects. The growth of all the saplings was monitored, as was the presence and damage by insects. After just six months, the differences between the two groups was dramatic. The insecticide treated trees were significantly taller, and had greater stem and root biomass. During this winter and spring periods, the greatest damage to the untreated trees seems to have been the tip wilting caused by Pomponatius typicus (Hemiptera: Coreidae) and the tip leaf death from Apion sp. B (Coleoptera: Brentidae). The biological control potential of these, and other Australian insects is being investigated.

48 ATTACHMENT AND INFECTION OF FUNGAL PATHOGENS ON SUBMERSED AQUATIC PLANTS

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In the search for host-specific pathogens for the biocontrol of Hydrilla verticillata and Myriophyllum spicatum, it has become necessary to understand some of the processes by which specific association occurs between host plants and microorganisms. This study employs a colonization assay designed to evaluate microbial specificity at the levels of: a) attachment, b) growth on the plant surface, c) plant penetration, and d) the production of disease symptoms. The isolation and partial purification of lectin glycoprotein from the two target plant species are also reported. Lectins have been implicated as a mechanism for specific association of microbes and submersed aquatic vegetation. Our work with lectins has led to the development of a parallel screening assay that enables us to identify pathogens which attach specifically to the target species.

49 ASSESSMENT OF VEGETATION IN TWO RIVERS ENTERING LAKE SUPERIOR USING LOW ALTITUDE AERIAL INFRARED AND COLOR PHOTOGRAPHY COUPLED WITH IMAGE ANALYSIS

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Aquatic macrophytes are to be planted as part of a remedial action program to restore and enhance wetland habitat in two rivers entering Lake Superior at Thunder Bay, Ontario, Canada. Prior to the establishment of new areas, existing vegetation and growth conditions were quantified using low altitude (1:5000 scale) color infrared and true color aerial photography, followed by field investigations of 13 sampling sites. The aerial photographs were scanned with a high resolution flatbed scanner and then classified for species using image analysis software. Biomass per unit area for each major species was estimated by field investigations. Sediment samples were also collected and measured for pH, P, N, Fe, Mn, Zn, Cu, Ca, Mg, and K. By combining individual species areas determined from the image analysis procedure with biomass estimates from the field data, total biomass was calculated for each species in the rivers. The color infrared photos were effective for classifying emergent and floating-leaved macrophytes, but submersed species were not as easily distinguished because of the low sensitivity of infrared film to wavelengths of light that penetrate the water. Scanned images of true color photos were better able to detect submersed species. Vegetation establishment within the rivers was largely limited by a lack of organic matter and small littoral zones caused by large wind fetches or boat wakes. Weirs will be constructed at suitable locations to counter such scouring actions and permit sediment to accumulate. The image analysis technique was considered an effective and economic method of assessing the present conditions and will be used in future to monitor vegetation changes.

50 CHANGES IN PLANT COMMUNITY STRUCTURE FOLLOWING LIMING OF AN ACIDIFIED ADIRONDACK LAKE

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Woods Lake has been the focus of a long-term study initiated in 1984 to investigate the effects of liming on lake trophic interactions and biogeochemical cycles. Aquatic plant communities were surveyed during 2 years prior to liming (1981 and 1984; lake pH < 5) and for 7 years after liming during which lake pH ranged from 5.5 to 6.5 (1985-1991). The most conspicuous effect associated with liming was the decline of the deep-water plants (depth range = 2-5 m). Utricularia purpurea was the dominant deep-water plant and accounted for 75% of total plant coverage in Woods Lake. Within 3 years following liming, Utricularia had declined severely and by 1990 represented less than 5% of community coverage. Floating-leaved and canopy-forming species have increased in percent coverage (from <0.5% to 7% of lake bottom area) and in relative abundance (from 10% to 40% of

community coverage). The most successful of these was Potamogeton epihydrus which was first observed in the lake 3 years after liming and is now the most abundant species (17% of community coverage). The shift in plant growth forms from deepwater to canopy-forming species is attributed to the decrease in the transparency of the lake as a result of liming.

51 CHANGES IN THE PLANT COMMUNITY OF CHAUTAUQUA LAKE, N.Y., BETWEEN 1937 AND 1991

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Chautauqua Lake is a quite large (5324 ha) lake located in western New York. It consists of two distinct basins with the northern basin being mesotrophic and the southern basin eutrophic. The lake has been heavily used for recreation for over 100 years and is an extremely important economic resource in western NY. The aquatic plant communities were surveyed in 1937, 1972, and 1991. Remarkable changes have occurred, including the introduction of new species, dramatic declines in diversity, and changes in species dominance. Fish populations have also changed dramatically during the past 25 years. Substantial use of aquatic plant management techniques began about 1970, including herbicides (mostly Diquat) and mechanical harvesting. Currently Potamogeton crispus and Myriophyllum spicatum are the dominant species, although P. crispus appears to be displacing M. spicatum in some areas. In the areas sampled over the past 55 years, diversity has declined dramatically and over the past 20 years the dominant species in the areas sampled has changed again, with diversity remaining very low. The current dominant species may be species less sensitive to Diquat, even in areas which have not been treated with chemical herbicides.

52 SEASONALITY OF COMMUNITY COMPOSITION AND BIOMASS FOR SELECTED SUBMERSED AQUATIC MACROPHYTES, LAKE OKEECHOBEE, FLORIDA

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Monthly submersed macrophyte biomass samples were collected in triplicate from three sites in Lake Okeechobee, Florida between December 1990 and December 1991. Submersed taxa included Najas guadalupensis (Spreng.) Magnus, Hydrilla verticillata Royle, Vallisneria americana Michx., Potamogeton illinoensis Merong, and Ceratophyllum sp. Lake stage increased during the study period from 0.5 to 2.18 m. There was a significant negative correlation between water depth and submersed macrophyte biomass ($p. \leq 0.05$). Najas was most negatively affected by changes in lake stage whereas Hydrilla was least affected. Biomass samples were dried, weighed for total biomass (mean = 452, range = 35 to 1,492 g m^{-2} dry weight), and partitioned into component species contribution. The epiphytic algal community was removed from subsamples of each macrophyte sample and analyzed for total chl a. Epiphytic algal production was not related to differences in lake stage. This research was sponsored in part by a contract between the South Florida Water Management District and the University of Florida.

53 ENVIRONMENTAL FACTORS AFFECTING SUBMERGED MACROPHYTE COMMUNITIES IN REGULATED WATERBODIES IN EGYPT

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Regulated waterbodies, used to generate hydro-electric power, have a number of features which differentiate them from natural waterbodies. The submerged vegetation of three regulated Egyptian waterbodies

(Lake Nasser, Aswan Reservoir, and the River Nile at Aswan) is described in relation to 25 environmental variables. Although interconnected, the three target waterbodies show major differences in water-level regime, produced by the requirements of operating schedules for power generation at the Aswan High Dam and Aswan Dam hydro-electric stations. These differences have major implications for physical conditions in the three waterbodies.

Submerged macrophyte growth, distribution, and community composition were directly related to environmental variables using the ordination procedure Detrended Canonical Correspondence Analysis (DCCA). The results suggested that variation in the submerged vegetation was most closely related to (i) hydrosoil Ca^{2+}, Mg^{2+}, and organic matter; (ii) water NO_3^-; and (iii) elevation. The implications of these results for assessment of environmental impact on macrophyte vegetation in regulated waterbodies are discussed.

54 THE DISTRIBUTION, ECOLOGY AND CONSERVATION OF LURONIUM NATANS (L) RAF. IN BRITAIN

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Strangely, despite a wide ecological amplitude, Luronium natans remains a rare aquatic plant endemic to Europe. The main populations occur in Britain, where Luronium is found in clear water lakes, navigation canals and ponds, with widely ranging water chemistry and associated plant communities. The spread of the plant this century from upland to lowland sites via an interconnecting system of waterways is chronicled. Luronium is a permanent member of the flora in lakes where disturbance by waves produces a stable, low biomass, open structured vegetation. It also occurs prolifically as an early colonist of recently disturbed, often artificial habitats, but in later stages of succession is out-competed by more vigorous species. Luronium is, therefore, transient or erratic in artificial situations because it depends on sustained human disturbance to arrest hydroseral succession and maintain its habitat. Dealing primarily with canal sites, the problems of habitat management and conservation of Luronium are discussed.

55 POTENTIAL FOR RE-ESTABLISHMENT OF MACROPHYTES IN A SHALLOW COASTAL LAGOON IN NEW ZEALAND

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The path of aquatic vegetation succession observed over a two year field study period in the stressed and disturbed Lake Ellesmere, a shallow coastal lagoon (South Island, New Zealand), has shown a tendency to evolve from stress-tolerant ruderals (like Lamprothamnium papulosum, Lepilaena bilocularis, Ruppia polycarpa) to C-S-R strategists (like Potamogeton pectinatus) following a period of decrease in the intensity of perturbations (less lake-level fluctuations during plant growth and less turbulence). A further decrease in a very calm embayment led to the development of the stress-tolerant competitor Ruppia megacarpa.

In an habitat deprived of any permanent stands of perennials, generative strategies may prevail over vegetative growth. Their importance may also have been underestimated prior to a major storm event in 1968 that washed away dense beds of R. megacarpa. Potential remaining "safe sites" prior to the storm, may have been invaded through generative development under favourable conditions of low salinities, providing a genotypic variety and thus a margin of safety against environmental hazards. Historical evidence supporting this theory is presented. Such considerations might be very important in the formulation of a macrophyte management policy for the lake.

56 ECOLOGICAL DIFFERENTIATION OF POPULATIONS OF UTRICULARIA MINOR L. AND UTRICULARIA INTERMEDIA HAYNE

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It has been stated that differentiation of natural populations of Utricularia minor and Utricularia intermedia is conditioned by water and base chemistry. On the grounds of biometric analysis of individual and group features of U. minor and U. intermedia and also mineral nutrients analysis in these plants, effects of habitat chemistry on size and growth of examined plants have been stated. The bladderworts microhabitats are not very different with respect to water and base chemistry and ecological amplitude of these plants is not of a wide range. Optimum habitat conditions of U. minor and U. intermedia have been stated. The effectiveness of the active protection of these plant species (introduction, metaplantation, preservative culture) depends to a high degree upon the knowledge of their autecology. These species are classified as to their status as rare in Poland. At the Botanical Garden in Wroclaw (Poland) the cultivation of U. minor and U. intermedia is carried on.

57 CONDUCTIVITY: A MEASURE OF MEMBRANE INJURY OF AQUATIC PLANTS

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Many contact herbicides act by damaging the cell membranes of submersed nuisance aquatic plants causing loss of osmoregulation capacity. As a result of membrane damage, ions from the cytoplasm may leak to the surrounding water. Both the electrochemical potential of the cell and surrounding water will change and can be measured by specific conductance. If a general measure of cell injury is desired, measurement of conductivity can be utilized. A more specific measure of plant injury can be obtained using ion chromatography. Myriophyllum aquaticum and M. spicatum were exposed to physical (grinding) and chemical (herbicides) stresses, which affect the cell membrane. Cytoplasmic ion release to the surrounding water caused significant increases in conductivity (μmhos/cm) in surrounding water. This technique for measuring plant injury can be applicable to laboratory studies and efforts are underway to adapt the technique for utilization in field studies.

58 METHODS FOR EVALUATING THE ACTIVITY OF AQUATIC HERBICIDES

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Part of the mode-of-action of several aquatic herbicides is cellular disruption which results in ion leakage. This disruption is ultimately caused by the generation of oxygen radicals. The mechanism through which oxygen radicals are generated differs and in certain cases can be distinguished using chlorophyll fluorescence. Ion leakage (under dark and light conditions) and chlorophyll fluorescence from leaf tissue exposed to varying concentrations (0.0, 0.1, 1.0, 10, 100, 1000, and 10,000 μM) of several herbicides were monitored over a 72 hour period. All herbicides caused elevated ion leakage in the light while only certain herbicides caused similar amounts of ion leakage in the dark. The herbicides evaluated either increased, decreased, or had no effect on chlorophyll fluorescence. Herbicides that increased chlorophyll fluorescence probably generated oxidative stress by inhibiting photosynthetic electron transport. Certain herbicides had no effect on fluorescence and did not cause leakage in the dark. Therefore, photosynthesis is required for herbicidal action, but an alternative method for determining the mechanism that decreased fluorescence also caused ion leakage in the dark, indicating that oxidative stress can be generated without photosynthesis. Since many aquatic macrophytes persist in those areas of low light, the normal action of photodynamic herbicides may be limited. Thus, alternative mechanisms-of-action may play an important role in the activity of these compounds.

59 INTERACTIVE EFFECTS OF PHOTOPERIOD AND FLURIDONE ON HYDRILLA VERTICILLATA

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The interactive effects of photoperiod and fluridone on hydrilla were determined by evaluating changes in morphological, phenological, and physiological characteristics over time. Two and eight month old hydrilla plants were exposed to either long or short-day lengths and 0, 0.05, 0.5, 5.0, or 50 ppb fluridone. Plants were treated and maintained in 900 liter concrete vaults. Fresh and dry weight, number of shoots, flowers, turions and tubers, and the concentration of anthocyanins, carotenoids, chlorophylls, and abscisic acid were determined 0, 2, 4, 6, 8, and 12 weeks after treatment. Short day conditions promoted flower, tuber, and turion production in mature plants but only tuber production in younger plants. Low concentrations of fluridone (0.05 and 0.5 ppb) caused a transient stimulation in growth and vegetative propagule number but higher concentrations (5 and 50 ppb) inhibited these parameters. Short days increased the level of abscisic acid but had no effect of the levels of the three pigments. Fluridone at 5 and 50 ppb caused a decrease in chlorophylls and carotenoids. Anthocyanin levels increased with increasing fluridone concentrations. Fluridone directly inhibited carotenoid and abscisic acid biosynthesis which resulted in a decrease in chlorophyll content and consequently growth. The surprising stimulation of anthocyanins by fluridone is presently under investigation.

60 EFFECTS OF FLURIDONE ON CAROTENOIDS, CHLOROPHYLL AND ANTHOCYANINS IN HYDRILLA VERTICILLATA

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Fluridone has been reported to specifically inhibit carotenoid biosynthesis in susceptible plants. The inhibition of carotenoids causes the photooxidation of chlorophyll which often results in a "bleached" or white plant. However, several plant species produce pink, red, or purple coloration in response to fluridone. For example, cucumber turned white in response to fluridone, but tomato, hydrilla, common duckweed, coontail, and torpedo grass became pigmented. Extraction of the pink pigment present in fluridone treated hydrilla shoot tips confirmed the presence of anthocyanins. The extract showed an absorbance peak at 530 nm in acidic methanol and discolored at neutral pH. Anthocyanin levels increased four-fold in hydrilla treated with 50 ppb fluridone while carotenoid and chlorophyll levels were reduced by 100 and 80%, respectively. Therefore, a dynamic interaction may occur between these three pigments in response to fluridone. Investigations are currently underway to determine if fluridone directly or indirectly regulates chlorophyll and anthocyanin biosynthesis in hydrilla.

61 AHAS, A NEW ENZYME TARGET IN AQUATIC PLANT HERBICIDE CONTROL

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The aquatic herbicide Mariner® (Bensulfuron methyl) is currently being tested for its effectiveness in controlling nuisance aquatic plants such as Hydrilla verticillata (L.f.) Royle. Mariner® is a member of the class of herbicides known as the sulfonylureas. The mechanism of action of the sulfonylureas is complex and involves the inhibition of the enzyme acetohydroxyacid synthase (AHAS, E.C. 4.1.3.18). This is the first enzyme unique to the biosynthesis of the branched-chain amino acids leucine, isoleucine and valine. We extracted AHAS from H. verticillata and have conducted a partial characterization of the protein. AHAS from Hydrilla has a relatively high temperature optimum (43-50°C) and a pH optimum of 7.4. The substrate for AHAS is pyruvate with a K_m of 13 mM. The reaction is saturated at 100 mM. This enzyme also requires three cofactors. The reaction is saturated at the following cofactor concentrations: thiamine pyrophosphate, 0.5 mM; $MgCl_2$, 10 mM; flavin

adenine dinucleotide, >200 nM. In vitro inhibition of AHAS by Mariner® was dramatic. With the addition of only 1nM of herbicide, a 25% inhibition of enzyme activity was observed. Increases in herbicide concentration caused significant increases in inhibition (1 μM - 93% inhibition). The I_{50} was calculated to be 20 nM. In vivo experiments on H. verticillata are in progress.

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62 PEROXIDASE LEVELS AS INDICATORS OF HERBICIDE-INDUCED STRESS IN AQUATIC PLANTS: TECHNIQUES FOR ANALYSIS

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Increase in peroxidase enzyme (PRX) content, and change in number of isozymes being expressed, are associated with reactions to environmental stress in terrestrial and aquatic plants. Such alterations may have predictive value for subsequent control of submersed weeds. Two aquatic species, Eurasian watermilfoil (Myriophyllum spicatum L.) and hydrilla (Hydrilla verticillata (L.f.) Royle), show elevated PRX when exposed to treatment concentrations of aquatic herbicides. In order to evaluate post-application enzyme levels accurately, baseline PRX activity in untreated plants and optimal extraction/analysis conditions are being determined. Reactions of crude plant homogenates with guaiacol or phenol in the presence of H_2O_2 show that hydrilla and milfoil differ in their specificity for these PRX substrates. Individual tissues vary in enzyme levels before and after treatment. Roots tend to have high levels; leaf activity is elevated but responsive to herbicide stress; tip tissue (whole shoot <5 cm) and stems have less activity. Electrophoresis of plant extracts in starch gels allows visualization of individual PRX isozymes, and monitoring of their presence or absence in tissues following herbicide application.

63 LEAF DISK/SHOOT SECTION CONTAMINANT BIOASSAY SYSTEMS FOR AQUATIC MACROPHYTES

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The development of aquatic macrophyte systems for toxicological modeling and assessment has remained an important but unresolved problem. Our laboratory group has developed short-term photosynthetic (C^{14})-carbon assimilation (PCA) bioassay protocols for leaf disk sections from pondweed Potamogeton amplifolius and shoot sections from cultured seedlings of the water lily Nelumbo lutea. In Nelumbo, a petiole elongation rate bioassay was also developed. Potamogeton leaf disk data suggested that additions of hexavalent chromium and copper (0.5 μg to 10 mg/l) to lake water incubation media produced ecologically significant changes in PCA rates (15 min - 4 h bioassays). However, the effects were not dose-specific and EC-50 values were difficult to compute. In Nelumbo shoot section bioassays (4 - 96 h), chromium at levels as low as 0.5 mg/l induced a strong stimulation of PCA. Shoot elongation rates in Nelumbo were strongly and dose-specifically repressed (EC-50 ca. 5 mg/l) by exposure to chromium (48 and 96 h bioassays). We are currently investigating the role of dissolved humic materials (DHM), alone and in concert with heavy metals, as effectors of PCA and petiole elongation. Taken together, the data suggest that the above short-term macrophyte bioassay systems hold promise as model ecophysiological and contaminant modeling systems.

64 MACROPHYTE STANDS AS A HABITAT: ENVIRONMENTAL FACTORS AND STRUCTURE

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Aquatic macrophytes provide habitats for numerous aquatic organisms, e.g. autotrophic and heterotrophic turf and vertebrates, but also spawn and juvenile stages of higher vertebrates. Important is the structure of weed beds which reflect the architecture of sole plants. These spatial differentiations can be described by different variables, such as the vertical distribution of biomass, leaf area indices, the number of leaves, stems, and branchings, the numeric description of the spatial distribution of individual leaves or their mean spatial distances. The authors present data on the vertical distribution of biomass and related architectural parameters in several species of submersed aquatic macrophytes and their influence on the vertical light gradient and current velocity, respectively. The discrimination of structural types is discussed in an attempt to extend present concepts of the spatial distribution of different plant structures.

65 CHANGE IN SUBMERGED MACROPHYTES AND FILAMENTOUS ALGAE IN GREEN LAKE, WISCONSIN, FROM 1921

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In 1921, H.W. Rickett surveyed aquatic plants in this pristine lake and his data and methods are the basis for 50, 60, and 70 (and/or 10 and 20) year comparisons. Submerged macrophytes and filamentous algae were collected in 1/4 m^2 quadrats, separated, weighed, and both wet and dry weights in g/m^2 were computed. In 1971, ten of Rickett's 41 stations along the 43.9 km of shoreline were selected in each of 3 zones (depths) to include the five highest and the five lowest in wet weight total values. Thus, random sampling was done in a total of 30 stations (always the same ones) for each of the study years of 1971, 1981, and 1991 to compare with the same stations in 1921.

Between 1971 and 1991, Myriophyllum spicatum and Potamogèton crispus have declined in importance, with M. sibiricum present now with a biomass equal to its exotic relative. Filamentous algae, mainly Cladophora, is only recently showing a slight decline. In the late 70's, a wastewater treatment plant on an inlet was improved and an aquatic weed harvesting program started. A voluntary non-point pollution program of 10 years is almost ended for the watershed of 27,618.8 ha which is 86% in agriculture.

66 SEASONAL RELATIONSHIP BETWEEN SOUTHERN NAIAD AND ASSOCIATED PERIPHYTON

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Periphytes growing on Najas guadalupensis were collected monthly to determine their relationship to the seasonal decline of southern naiad in south Florida. Periphyte biomass was determined indirectly by measuring the chlorophyll a of cells suspended after separation from apical portions of the macrophyte and reported as g chlorophyll a / g DW of macrophyte. The periphyte community was dominated by Bacillariophyceae, Cyanophyceae and Chlorophyceae, and the percent composition of these dominant groups changed seasonally. A significant inverse relationship was determined between periphyte and macrophyte biomass. Other related parameters such as light transmittance, temperature, and water nutrients were considered.

67 RELATIONSHIPS BETWEEN SUBMERGED MACROPHYTES AND ALGAE IN FRESHWATER LOCHS OF DIFFERING TROPHIC STATUS

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Studies have been carried out on four freshwater lochs in Scotland supporting differing standing crops of algae (phytoplankton, epiphytes, and benthic filamentous mats), to examine the relationship between algal growth and success of the submerged macrophyte Littorella uniflora (L.) Ascherson. The target lochs (Loch Dee, Loch Lomond, Loch of Lowes, and Lake of Menteith) ranged from acidic and oligotrophic, to moderately eutrophic with pH>7.0.

During 1990 and 1991 the growth and standing crop of Littorella, benthic algae, and phytoplankton were regularly monitored using SCUBA techniques at a range of sites in each loch. Underwater light climate and water chemistry variables were also recorded. Adaptations of Littorella to the growth conditions produced by differing quantities and forms of algae present were examined. The results have implications for the question of macrophyte loss from waters undergoing eutrophication or acidification processes.

68 AQUATIC MACROPHYTES VERSUS PHYTOPLANKTON IN LAKES: A PRACTICAL MANAGEMENT GUIDE

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Water quality and aquatic macrophyte data from 60 Florida lakes and long term (n > 10 years) data before and after total removal of aquatic macrophytes on a subset of three lakes, were used to examine the whole-lake relations between aquatic macrophytes and phytoplankton populations. Percent area covered and percent volume infested with aquatic macrophytes were inversely related to chlorophyll a concentrations and directly related to secchi depth, both indicators of phytoplankton biomass, demonstrating an inverse relation between phytoplankton and aquatic macrophytes. Total phosphorus and nitrogen content of aquatic macrophytes and associated epiphytic algae garment in the lakes were measured and multiplied by the total lake plant biomass to determine a potential lake concentration of phosphorus and nitrogen. These values were then used with a model estimating a chlorophyll a concentration from the potential total phosphorus and total nitrogen concentration, which is a chlorophyll a value that could potentially exist if the nutrients incorporated in aquatic macrophyte tissues were expressed as phytoplankton cells. Adding the potential to the measured chlorophyll a concentration of a lake yields an adjusted chlorophyll a concentration that can then be used to calculate the trophic level of lakes with abundances of aquatic macrophytes and determine what changes in chlorophyll a concentration and water clarity can be expected from aquatic macrophyte control programs.

69 RELATIONS OF MYRIOPHYLLUM AND OTHER MACROPHYTES TO SEDIMENT CHARACTERISTICS IN BACKWATERS OF THE RIVER DANUBE (LOBAU-AREA, VIENNA)

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The Lobau-area is a large natural sanctuary within the boundaries of the City of Vienna, Austria. It consists of senescent riverine forests and waterbodies, separated from the main channel by a dam which permits floods to enter from a downriver inlet only. Restoration of the area is envisaged in context with the construction of a hydro-electric powerplant, supplying water for the system of old channels. Before the outset of a permanent flow into the system, a comprehensive study on biotic and abiotic factors was started, including the mapping and classification of sediments and macrophytes. Relations of sediment and macrophytes are presented. Some aspects of Myriophyllum species occurring in the area are discussed.

70 PRODUCTIVITY OF SUBMERGED MACROPHYTES AND ASSOCIATED EPIPHYTES, LAKE OKEECHOBEE, FLORIDA

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Submersed macrophyte samples were collected in triplicate from nine sites in Lake Okeechobee, Florida during March 1990 - August 1991 and analyzed for productivity and turnover time. C-14 incubations were made bimonthly for three species (Hydrilla verticillata Royle, Vallisneria americana Michx., Potamogeton illinoensis Merong). Lake stage increased during the study period. Average macrophyte productivity exceeded 1.1 $gC/m^2/d$; epiphyte productivity exceeded 1.5 $gC/m^2/d$. Turnover time for the macrophytes averaged 10 days, epiphyte turnover was ca. 5.5 days. This research was in part sponsored by a contract between the South Florida Water Management District and the University of Florida.

71 LABORATORY EVALUATIONS OF FLURIDONE CONCENTRATION AND EXPOSURE TIME REQUIREMENTS FOR CONTROL OF HYDRILLA AND EURASIAN WATERMILFOIL

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The efficacy of fluridone treatment for control of the submersed aquatic plants hydrilla (Hydrilla verticillata (L.f.) Royle) and Eurasian watermilfoil (Myriophyllum spicatum L.) is dependent on the length of time the plants remain exposed to given concentrations of the herbicide. Excellent plant control has been obtained by single applications of fluridone to approximately 20% of the surface area of enclosed systems and multiple applications in flowing-water systems. Moreover, the success of these treatments has been linked to maintaining low concentrations of fluridone in the water column for an extended period of time. However, these results have only broadly quantified the relationship between fluridone concentration, exposure time, and subsequent plant control. Laboratory studies have been conducted to determine the efficacy of fluridone at concentrations ranging from 5 to 100 $\mu g/l$ and exposure times ranging from 3 to 77 days. Data indicate that at high label rates, exposure times of less than 14 days were ineffective and resulted in biomass reductions of 15 to 39%; whereas concentrations as low as 12-24 $\mu g/l$ for 35 to 42 days resulted in biomass reductions of 80 to 95%. Further quantification of the relationship between fluridone concentration, exposure time, and plant control will provide guidance for improving the control of target plants using this herbicide.

72 CONCENTRATION/EXPOSURE RELATIONS OF FLURIDONE ASSOCIATED WITH HYDRILLA MANAGEMENT IN THE WITHLACOOCHEE RIVER, FLORIDA

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To manage the abundant growth of hydrilla in the Withlacoochee River, Florida, in 1990, fluridone was applied over a period of 13 weeks to six lakes along the targeted section of river. Under conditions of low water discharge that spring, a year's hydrilla control was achieved over 38 km of river. Extensive residue sampling indicated that although the objective concentration of 10-12 $\mu g\ l^{-1}$ was not sustained for 13 weeks, hydrilla was susceptible to lower concentrations over long exposure periods. These concentration/exposure relations were related to water flow data, particularly the influence of springfed tributaries of the Withlacoochee, downstream of which the longevity of hydrilla suppression was reduced, and to the changes in plant communities observed at permanent mapping transects. The treatment was repeated in 1991 under increased flow conditions, which caused some reduction in the longevity of hydrilla control.

73 IMPACTS OF WETLAND VEGETATION FROM A LARGE SCALE SONAR™ APPLICATION

Terence M. McNabb and Thomas Clingman, Resource Management/Aquatics Unlimited, Kent, Washington, and Thurston County Public Works, Olympia, Washington.

Long Lake is a 330 acre waterbody in Thurston County, Washington infested with Eurasian Watermilfoil. In 1991, a large scale Sonar™ Herbicide block treatment scenario was developed to attempt eradication of this plant from the lake. The plan was developed by Thurston County Public Works with input from USAE WES, Washington Department of Ecology, and Aquatics Unlimited. Long Lake has a number of sensitive wetlands adjacent to the lake and along the outlet canal. In order to get the permits required to make the application, a wetland monitoring and loss mitigation program had to be developed. Transects were established from the upland boundary to deep water and plant species abundance were recorded for the pre-treatment baseline. In addition, the wetlands were recorded on an aerial video imaging system. The pre-treatment data was collected June 14, 1991. The Sonar treatment was performed in blocks on July 2, July 17, July 31, and August 14.

In June of 1992, the transects will again be surveyed and airborne video imagery collected. The Water Watch™ Image Processing software will then be used to determine the area of any plant loss for mitigation. This paper will compare the 1991 survey and image data to the 1992 data and discuss the effect of the treatment on wetland communities adjacent to and downstream of the lake.

74 EFFECT OF RODEO® ON DIFFERENT DENSITIES OF EICHHORNIA CRASSIPES

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Water Hyacinth is a problem in rivers and reservoirs of Mexico and appropriate control methods are needed. This study evaluated the phytotoxic effect of the herbicide glyphosate (Rodeo®) in water hyacinth infested areas of the reservoir Endho, Estado de Hidalgo, Mexico. Duplicate $1m^2$ areas containing 10, 20, 30, and 40 kg/m^2 densities of water hyacinth were randomly established. After a 2-week acclimatization period, two doses of glyphosate (5 l/ha and 7 l/ha) were applied to the plots, the plots were evaluated at 9, 19, 33, 51, 72, and 94 days after treatment. Glyphosate at 5 l/ha (2.38 kg/ha acid) effectively controlled densities of 10 and 20 kg/m^2 in 51 days. At higher plant densities (30 and 40 kg/m^2), a second application of glyphosate at day 51 of 2 l/ha (0.95 kg/ha) was necessary to achieve plant control. Further studies have shown that the second application applied 20 to 30 days after the first provides good results in high density areas.

75 CHEMICAL CONTROL OF EMERGENT AQUATIC WEEDS IN THE IRRIGATION SYSTEM IN THE SUDAN

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Aquatic weeds constitute a serious problem to irrigated areas in the Sudan. The total length of the irrigation system in the Gezira scheme is 68,000 km. Chemical control method was investigated to solve the aquatic weed problem besides manual and mechanical measures used. Roundup herbicide at 0.65, 0.86, 1.08 and 1.5 kg ai/fed. was applied on plots with buffer area (20 x 5 m each) arranged in a randomized block design with 5 replicates with a knapsack sprayer at a vol. rate of 120 l/fed. in June 1991. 70.67 %, 58.28 % and 54.67 % control of Typha latifolia, Polygonum glabrum and Vossia cuspidata, and Echinochloa stagnina respectively was obtained at 1.08 kg ai/fed. and the results for the same species at 0.86 kg ai/fed. were 57.33 %, 55.02 % and 45.93 % respectively. The variation in the results obtained may be due to the weed species and rate used.

76 FATE AND PERSISTENCE OF HERBICIDES FOR CONTROL OF HYDRILLA VERTICILLATA AND MYRIOPHYLLUM SPICATUM IN GUNTERSVILLE RESERVOIR, ALABAMA

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The objective of this study was to determine herbicide partitioning and persistence in water, sediments, fish, mollusks, and plant tissue in Guntersville Reservoir, Alabama. Herbicides were applied to critical priority treatment areas to control excessive growths of Hydrilla verticillata and Myriophyllum spicatum. This was a joint agency project of the Tennessee Valley Authority and the U.S. Army Corps of Engineers-Waterways Experiment Station. Herbicides used in this study included fluridone, 2,4 dichlorophenoxy acetic acid (dimethyl amine formulation [2,4-D DMA]), endothall, diquat, and copper. The herbicides were effective in controlling growths of these plants in treated areas. Herbicide persistence and partitioning were predictable based on their structural and fate characteristics and the margin of safety for nontarget species and resources was maintained.

77 EFFICACY OF BENSULFURON METHYL ON AQUATIC MACROPHYTES IN TWO CENTRAL CALIFORNIA PONDS

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Bensulfuron methyl is an herbicide currently being tested for the management and control of aquatic weeds. West Pond and Lido Pond are shallow ponds (≤ 2.5 m deep) located on Venice Island that were treated with bensulfuron methyl at a rate of 50 ppb and 75 ppb, respectively, during the mid-season 1991. At the time of treatment, West Pond contained Pondweeds (Potamogeton pectinatus, P. crispus and P. foliosus) evenly distributed throughout the pond. Lido Pond was completely covered by a dense mat (249 ± 32 $g \cdot m^{-2}$) of Eurasian watermilfoil (Myriophyllum spicatum L.) and P. pectinatus with a trace of water primrose (Ludwigia peploides) growing along the banks. Plant control in both ponds was determined by monthly sampling of the above-ground biomass for 6 months. At the same time, water samples were collected and later analysed for herbicide concentration. Complete control of all Pondweeds and water primrose was observed at 1 month in both ponds, and 100% control of Eurasian watermilfoil was observed after 3 months in Lido Pond.

78 LABEL UPDATE ON RENOVATE AND SONAR AND RECENT SONAR RESEARCH RESULTS

David Tarver, DowElanco, 1499 Morning Dove Road, Tallahassee, Florida 32312.

A registration submission for Renovate was made in November, 1990 to the EPA. The responses to data submissions to support tolerances for triclopyr in water, fish, shellfish, and irrigated crops was received in January, 1992. Only a minor amount of additional information was requested from the product chemistry, toxicology, ecological effects, environmental fate, and groundwater review groups. New studies were requested by the residue chemistry group and those data requests are being evaluated.

In Georgia, a 24-C registration to approve use of Sonar AS in slow flowing rivers, creeks, and streams was granted in 1991. A similar Florida submission has recently been made. As a result of the flowing water trials conducted under an EUP, fluridone levels as low as 15-30 ppb were found to provide hydrilla control when exposure length was 30 to 60 days. Additional research (Personal Communication, Haller 1992) indicates a rate of 5 ppb fluridone may inhibit hydrilla tuber formation and 10 ppb may provide control. Field research efforts continue to improve fluridone's selective efficacy.

79 SEED PRODUCTION IN MONOECIOUS AND DIOECIOUS POPULATIONS OF HYDRILLA

Kerry K. Steward, Aquatic Weed Research, U.S. Department of Agriculture, Agricultural Research Service, 3205 College Avenue, Fort Lauderdale, Florida 33314.

The potential for sexual reproduction was evaluated in the various races of our international hydrilla germplasm collection. Crosses between the various dioecious and monoecious hydrilla races resulted in seed production in 71% of the 56 crosses. Seeds from 90% of these crosses were viable and most seedlings survived. The dioecious female plant, established in the U.S. since the 1950's having never been reported to produce seed, was discovered to be one of the greatest seed producers. It has been reported to be triploid but seed from 4 of its 5 crosses were determined to be viable. Triploids are generally considered to be sterile so these findings raise serious questions about the reported ploidy level of this plant. Another observation, not previously reported for hydrilla, was the occurrence of monoecious offspring from dioecious parents. This was taken as evidence of the presence of sex chromosomes in hydrilla, an observation first reported in 1928 by Japanese scientists. The reported lack of seed production in the U.S. dioecious female has been due to the absence of a viable pollen donor. The need for continuing vigilance in preventing further introductions of hydrilla is obvious.

80 MECHANISMS OF COEXISTENCE OF SUBMERGED MACROPHYTES IN TEMPORARY MARSHES. ROLE OF THE SEED BANK AND THE REGENERATION PHASE.

Anne Bonis, Patrick Grillas and Jacques Lepart, Station Biologique Tour du Valat - CEFE-CNRS Montpellier, France.

The role of the seed bank in the maintenance of diversity in submerged macrophyte communities of temporary marshes has been investigated. In these marshes, competitive exclusion could be avoided by recurrent disturbance (drought which destroys biomass) and by fluctuations of populations. These interannual fluctuations could arise from the irregular rainfall regime, different species having an advantage under different conditions of flooding (i.e. different temperatures). To maintain coexistence in annual communities, a seed bank must be present.

We have tested our hypothesis by surveys of the seed banks in two marshes during three years. An experimental approach permitted us to assess the temperature response of species (part of their regeneration niche), according to their rate and cinetic of germination. Seed bank populations and vegetation fluctuate between hydric years. We have shown the persistence of a large seed bank with a low depletion rate and an expected selective advantage which allows low density population to rebuild rapidly. The temperature of establishment discriminates between species, both on the rate and the cinetic of their germination. The maintenance of diversity in these annual communities appears to be tightly dependent on the variation of water regime and on the persistence of a seed bank.

81 GERMINATION, GROWTH AND DEVELOPMENT OF TWO NYMPHAEA SPECIES CONSERVED AT THE BOTANIC GARDENS OF TEL AVIV UNIVERSITY

Moshe Agami and Malgorzata Walczak, Department of Botany, Tel Aviv University, Tel Aviv 69978, Israel.

An analysis of the Israeli flora reveals that although constituting only about 10% of the local species, some 80% of the extinct and most endangered ones are water plants. This is due to the nearly total exploitation of water resources, which has caused an extreme and rapid change in natural ecosystems, reclamations of marshlands, lowering of the ground water level, and to the pollution of the remaining living waters. An example of such extinct plant populations can be seen in the water lilies. Both the white water lily (Nymphaea alba) and the blue water lily (Nymphaea caerulea) are presently being conserved at the Botanic Gardens. These

populations were unique because each represented in Israel the southernmost and the northernmost areas of distribution, respectively. Preliminary results of comparative studies on the ecophysiology of these two Nymphaea species, as well as the closely related Nuphar luteum, revealed that Nymphaea caerulea seeds could not germinate in darkness, whereas the germination rate in the light, at 25°C, was up to 100%. No germination occurred at 16°C and 20°C. The rate of seedling growth and development was strongly influenced by the kind of sediment (when the water column was kept uniform); high rates on a mixture of peat and sandy loam, lower on pure sandy loam, and lowest on sand. The results of complementary studies regarding growth and development, morphological patterns in established plants and physiological responses to particular environmental factors will also be discussed.

82 THE SIGNIFICANCE OF GERMINATION BEHAVIOR OF TYPHA SUBULATA ON WEED MANAGEMENT

Maria T. Sobrero, Osvaldo A. Fernandez and Mario R. Sabbatini, Facultad de Ciencias Agrarias, University Nacional de Santiage del Estero; CERZOS and Departamento de Agronomia, University Nacional del Sur, Argentina.

Seeds of Typha subulata allow this species to colonize new habitats and reinfest previously controlled areas. Freshly harvested seeds of T. subulata were stored at 4 ± 1° C and 23 ± 3° C in the dark under dry air conditions in paper bags or wet conditions by immersion in water. After 6 and 14 months, they were tested for germination at a 20° (dark)/30° (light) C daily thermoperiod and a 10 hour photoperiod. These environmental conditions were highly favourable for germination. After the 6-month-pretreatment, germination was close to 100% in all treatments. The 14-month-old samples showed a germination rate higher than 96% when they were maintained under dry conditions at both temperatures. However, samples kept under wet conditions showed 64 and 0% germination under the 4° and 21° C storage temperatures, respectively.

These results indicate that in infested irrigation districts of southern Argentina where the canal beds are subjected to periodical mechanical treatments, the possibility of reinfestation with this weed will be reduced if they remain permanently wet even during periods when they are not used.

83 VEGETATION, SEED BANKS AND SEEDLING ESTABLISHMENT IN TWO SOFTWATER LAKES: OBLIGATE SEXUAL REPRODUCERS DOMINATE

John Titus and Gary Sullivan, Department of Biological Sciences, State University of New York, Binghamton, New York 13902.

Asexual reproduction is surely the dominant propagating mode in many submersed plant communities. Vegetation sampling in two north temperate softwater lakes revealed similar communities dominated by spore-producing Isoetes spp. and the annuals Najas flexilis, N. gracillima, and Potamogeton spirillus, all obligate sexual reproducers. These taxa collectively constituted 80% of the 857 observations in 465 quadrats in one lake, and 70% of the 3,474 observations in 1,000 quadrats in the other.

Sediment cores collected in winter and exposed to 20°C in a greenhouse produced annual plant seedling densities from 70 to 690 m^{-2} and juvenile Isoetes densities from 1,400 to 12,600 m^{-2}, all from the top cm of sediment. Spring and early summer field sampling showed extremely variable seedling densities ranging from 0 (beneath perennials) to 2,960 m^{-2}, with Isoetes juveniles too dense to count. Seed/spore germination and seedling/juvenile establishment clearly occur readily, bringing about the predominance of sexual reproduction in these oligotrophic lakes.

84 POTAMOGETON PECTINATUS L. PROPAGULE GROWTH AND APPROACHES FOR MODELLING SURVIVAL OF SUBMERGED MACROPHYTES

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Propagule growth of a Potamogeton pectinatus L. population was investigated in a eutrophic shallow lake, Lake Veluwe (The Netherlands) under different light conditions. The photon flux density was experimentally manipulated by applying three levels of artificial shading an 100 m^2 plots. Furthermore, control plots without shading were distinguished. P. pectinatus propagule growth rate is clearly related to standing crop of above (including stems, leaves, flowers, and fruits) and below ground biomass (including roots and rhizomes), and to light climate. Mean individual propagule weight and the frequency distribution of propagules over distinguished weight classes under different light conditions during the course of the season are presented. It is concluded that competition for carbohydrates between tubers and above ground plant parts is a main determinant in P. pectinatus propagule growth rate. An exploration was made to model competition for carbohydrates between above ground biomass and vegetative propagules in macrophytes. Implications for models on survival of submerged macrophytes are discussed.

85 WATER MANAGEMENT PRACTICES INFLUENCE PLANT REPRODUCTION AND MACROPHYTE COMMUNITY COMPOSITION IN A NORTHERN CALIFORNIA IRRIGATION CANAL

David Spencer and Greg Ksander, USDA-ARS Aquatic Weed Laboratory, UC Davis, Davis, California 95616.

Information from measurements of a natural community and an experiment demonstrates that water management practices strongly influence aquatic plant reproductions and community composition. Data from the Byrnes canal indicate that winter buds of the dominant species, Potamogeton gramineus, were usually first observed in August. In 1990, winter buds were observed on June 22 following a period of reduced flow and water depth. We performed an experiment to test the hypothesis that reduced depth would influence winter bud formation. Two groups of plants were grown under similar conditions except that one was exposed to reduced water depth after eight weeks. Results demonstrated that P. gramineus treated this way initiated winter bud formation about two weeks before the control plants. This indicates that fluctuating water levels interact with photoperiod to influence initiation of vegetative propagules. In 1991, community composition shifted so that P. gramineus was replaced by Eleocharis sp.. Comparison of biomass at this and another nearby site indicated that changes in water management practices, specifically filling the canal earlier than usual in the spring, letting it dry out for about six weeks, and then refilling it, facilitated this change.

86 TURION PRODUCTION BY HYDRILLA

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Dioecious hydrilla (Hydrilla verticillata (L.f.) Royle) is the most widespread submersed aquatic weed in Florida and its spread and reproduction is limited to asexual means. Hydrilla produces two specialized reproductive propagules. Tubers (subterranean turions) are formed at the ends of underground rhizomes during short day conditions and turions (axillary turions) are formed in the axils of the leaves. Floating (non-rooted) hydrilla stems produced more turions than stems that were planted in the soil. Turion production on floating hydrilla stems begins in September and increases during October and November, decreases during December and January, and increases in the spring. Placing hydrilla stems in water containing 2.5, 5.0, and 10.0 $\mu g/l$ (ppb) bensulfuron methyl or fluridone significantly reduces turion production.

87 EXOTIC AQUATIC PLANT MANAGEMENT IN FLORIDA; HISTORY AND STATUS

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The Department of Natural Resources directs and coordinates aquatic plant management in the state of Florida. Four hundred sixty-five lakes and rivers, comprising a half-million hectares of fresh water, are accessible to the general public. Each year they are inventoried to monitor exotic (non-native) aquatic plants and to assess the effect of management programs. The most troublesome of the 19 exotic plants found in Florida waters are Eichhornia crassipes (waterhyacinth), Pistia stratiotes (waterlettuce), and Hydrilla verticillata (hydrilla). Ninety-seven percent of the $6.2 million spent managing aquatic plants in public waters in 1991 was for the control of these three species. This report focuses on the management of waterhyacinth, waterlettuce, and hydrilla; providing a history of their introductions, associated problems, management strategies, and the magnitude of Florida's management programs. After nearly 100 years of management, waterhyacinth and waterlettuce are now under control with fewer than 2,500 hectares reported in public waters. More than 14,000 hectares of these plants are controlled each year to sustain control. Hydrilla continues to expand, now covering 27,000 hectares in public waters despite approximately 6,000 hectares controlled each year.

88 AN OVERVIEW OF THE AQUATIC PLANT CONTROL OPERATIONS SUPPORT CENTER

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In October 1980, the Jacksonville District was designated by Headquarters, U.S. Army Corps of Engineers, as the Aquatic Plant Control Operations Support Center (APCOSC) in recognition of the District's knowledge and expertise gained through the administration of the largest and most diverse aquatic plant management program within the Corps of Engineers. APCOSC personnel provide assistance in the planning and operational phases of aquatic plant control to other Corps elements, federal, state, and local agencies as well as a variety of public and private individuals and/or enterprises. The demand for and type of services performed by the Center vary from year to year, based on the type of problems encountered by Corps elements and other agencies. Four basic types of information are provided: planning, operations, research, and training. This presentation will provide: 1) a historical retrospective of the APCOSC, 2) an overview of APCOSC functions, and 3) instructions on utilizing the APCOSC.

89 REVIEW OF BENEFITS OF THE BRITISH COLUMBIA AQUATIC PLANT MANAGEMENT PROGRAM

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Following about 20 years of management of aquatic plants in British Columbia, the rationale, objectives, methods, results, and costs of the program have been assessed. Eurasian watermilfoil control projects in 16 British Columbia lakes are being implemented by the Water Quality Branch and five local agencies. The Province provides most of the control equipment, gives technical advice on control methods and approaches and 75% of the funding, and monitors performance. Local authorities administer control, decide on treatment priorities, hire staff to operate equipment, and provide the remaining operating funds.

A consultant was selected to review the socio-economic benefits of management in one of the cost-shared projects, implemented by the Okanagan Basin Water Board in 8 Okanagan Valley lakes. The study reviewed available statistical data on the control project and the resources affected by Eurasian watermilfoil. Surveys of over 470 persons measured project effectiveness and benefits. Although treatments are made in

only 15% of littoral areas affected in these lakes, analysis showed that control has promoted economic development, that most residents and tourism operators are satisfied, and control is cost-effective. The analysis projected that termination of the control program (1990 cost $350,000) would lead to about $85 million decline of regional tourism revenues, and affect about 1,700 tourism industry jobs and $360 million of real estate values. Recommendations include support for cost-sharing, encouragement for more rotovation, and research on other longer-term control technologies, and greater efforts to advise the public on project results.

90 AQUATIC PLANT CONTROL ON THE KISSIMMEE RIVER: A TEN YEAR HISTORY

Jacqueline C. Jordan and Lloyd Mitchum, Florida Department of Natural Resources, 300 Business Park Way, Suite B-100, Royal Palm Beach, Florida 33411, and South Florida Water Management District, 1000 NE 40th Avenue, Okeechobee, Florida 34972, U.S.A.

Since completion of the U.S. Army Corps of Engineers' Kissimmee River Flood Control Project, the South Florida Water Management District has held the responsibility of aquatic plant control along the constructed main channel and within the remnants of the old river. Over the years, methods of plant control have changed along with the plant composition and the environmental mind set of the public. We will discuss the changes by examination of herbicide use over the last ten years along with integration of biological and mechanical control methods. Some implications of the Kissimmee River Restoration Project on aquatic plant control will be discussed.

91 THE INVASION OF SOUTH FLORIDA BY MELALEUCA QUINQUENERVIA (CAV.) BLAKE

Dan Thayer and Francois Laroche, South Florida Water Management District, P.O. Box 24680, West Palm Beach, Florida 33416.

Introduced into Florida from Australia in 1906, Melaleuca quinquenervia (Melaleuca) constitutes one of the greatest ecological threats to the biological integrity of the Everglades. Purportedly introduced to dehydrate Florida wetlands and create a timber industry in the region, Melaleuca has expanded rapidly in the last few decades. Hydroperiod manipulation and frequent fires have facilitated the spread of this exotic pest plant. It is estimated that Melaleuca is expanding at a rate of 20 hectares per day. At this rate of expansion, the Everglades will be overwhelmed by the Melaleuca tree in less than 50 years. Current estimates place the infestation level at a conservative 165,000 hectares. Management efforts include investigations into Australian insects, herbicides, fire, flooding, and possible utilization of the wood for mulch and as an alternative energy source. Methods of assessing infestation levels and expansion rates are discussed, as well as a review of efforts to manage the tree in the Everglades.

92 WATER RELATED PROJECTS OF THE IMPERIAL IRRIGATION DISTRICT

Randall K. Stocker, Planning and Technical Services Department, Imperial Irrigation District, P.O. Box 937, Imperial, California 92251.

As in many other arid areas of the world, southern California's dependency upon imported water through artificial waterways places unusual demands on system efficiency and the need to reduce aquatic plant growth. Historically, this dependency has meant large water delivery projects, with correspondingly large environmental impacts on other water resources of the state. Current efforts concentrate on improving efficiency of existing systems. More recently, the threat of reduced water delivery capacity to California's

irrigated desert areas from spread and growth of Hydrilla verticillata has resulted in the largest, and, to date, the most successful flowing water hydrilla eradication program yet conducted.

93 THE INFLUENCE OF VEGETATION PRE-DREDGING ON THE POST-DREDGING COMMUNITY

P.M. Wade, International Centre of Landscape Ecology, Department of Geography, Loughborough University, Loughborough, Leicestershire, LE11 3TV, U.K.

An investigation was undertaken as to the influence of vegetation in drainage channels pre-dredging on the development of the post-dredging community. This vegetation, present in a channel immediately before it is dredged, has a significant influence on the post-dredging vegetation in terms of species composition. Approximately 60% of the species recorded prior to dredging may be found in the first two years after dredging. Mean cover values of these species are much less in the post-dredging channel especially for species indicative of the latter stages in the channel hydroseral succession (e.g. Carex riparia and Phragmites communis). The most important elements of post-dredging vegetation were filamentous algae and floating species such as Lemna minor, L. gibba, and Hydrocharis morsus-ranae. Submerged species, appearing in channels post-dredging did not persist.

94 GROWTH AND TUBER PRODUCTION OF MONOECIOUS AND DIOECIOUS HYDRILLA IN THE UNITED STATES

Thai K. Van, U.S. Department of Agriculture, Agriculture Research Service, Ft. Lauderdale, Fl.

This paper summarizes results of recent studies on growth characteristics and tuber production in the U.S. monoecious and dioecious pistillate hydrilla biotypes. Competition between the two U.S. hydrilla biotypes and their differential responses to herbicide applications also will be discussed.

95 INTERNAL GAS TRANSPORT IN EMERGENT AQUATIC MACROPHYTES

Hans Brix and Brian Sorrell, Department of Plant Ecology, Aarhus University, Nordlandsvej 68, DK- 8240 Risskov, Denmark (for all correspondence), and The Murray-Darling Freshwater Research Centre, Ellis Street, Thurgoona, NSW, Albury 2640, Australia.

Internal transportation of gas in emergent aquatic plants may occur by passive molecular diffusion following the concentration gradients of the individual gases within the lacunal system, and by convective flow (i.e. bulk-flow) of air through the internal gas space of the plants. Convective flow of air in plants can be throughflow or non-throughflow and can be initiated by two purely physical processes, namely thermal transpiration and humidity-induced pressurization. Furthermore, venturi-induced convection, i.e. wind-induced convection has recently been documented for some wetland species. Non-throughflow convection may be driven by the same physical mechanisms, and in addition by solubilisation of respiratory carbon dioxide.

This paper reviews the different mechanisms of internal gas transport in emergent macrophytes, and present data from recent investigations on internal gas transport in different species. The investigations show that internal pressurization and convective throughflow of air driven by gradients in temperature and water vapour pressure seem to be common attributes of a wide range of wetland plants, including species with cylindrical and linear leaves. The ability of the individual species to produce a convective throughflow seems to be related to their ability to grow on deep-water sediments.

96 OXYGEN EXCHANGE BY ENTIRE ROOT SYSTEMS OF EMERGENT PLANTS

Brian K. Sorrell[1], Philip T. Orr[2] and Hans Brix[3], [1]Murray-Darling Freshwater Research Centre, P.O. Box 921, Albury NSW 2640, Australia;[2]CSIRO Division of Water Resources, Griffith Laboratory, Locked Bag 3, Griffith NSW 2680, Australia; [3]Botanical Institue, University of Aarhus, Nordlandsvej 68, DK-8240 Risskov, Denmark.

We used a bi-compartment apparatus, fitted with a polarographic oxygen electrode and a platinum wire electrode in the root chamber, to measure the net oxygen exchange by entire root systems of three emergent aquatic plants (Cyperus involucratus Rottb., Eleocharis sphacelata R. Br., and Juncus ingens N.A. Wakef.). The roots of all three species consumed oxygen from distilled water, with zero net oxygen exchange when the oxygen partial pressure (pO_2) in the chamber was zero. Rates of oxygen uptake by roots of intact plants were always lower than those of excised root systems, and were higher in the dark than in the light, suggesting a contribution by oxygen transport to the respiratory demand. The contribution of oxygen transport increased with diminishing pO_2, being ca. 0.5 of the total oxygen demand at pO_2 = 10 kPa, but > 0.9 of the oxygen demand at pO_2 = 0.1 kPa. The significance of this oxygen transport became evident when titanium (III) citrate redox buffer (E_H < -350 mV) was used in the root chamber. Excised root systems lowered E_H to ca. -500 mV; root systems of intact plants raised E_H, more rapidly in the light than in the dark.

97 EFFECTS OF METABOLIC PRODUCTS OF CELLULOSE-UTILIZING ORGANISMS ON HYDRILLA VERTICILLATA ROYLE

Brenda L. Pompey and Dean Martin, Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, Florida 33620-5250.

Hydrilla verticillata Royle is a rooted submersed, perennial plant that can occupy the top meter of water of Florida lakes, rivers, and canals, and is probably the number one nuisance aquatic plant in Florida. The plant was expelled into a canal in the late 1950's, and the plant has spread throughout Florida, the Southeast, and significant parts of Louisiana and California. Infestations of hydrilla can significantly affect the economic tempo of areas that depend upon tourism in Florida.

Our interest has been the occurrence of natural products that appear to inhibit the growth of hydrilla in lakes that have an organic sediment derived from cypress. It was possible to identify the hydrilla inhibitor through use of high performance liquid chromatography. The research is focused on isolating organisms that utilize cellulose and produce metabolic products that inhibit the growth of hydrilla. Sediment from Lake Starvation (a lake known to possess the inhibitor) was placed in Erlenmeyer flasks containing sterilized growth media with cellulo-biose as a carbon source. After ten days, the filtrate was collected, sterilized, and a bioassay was run using hydrilla. The results indicate the presence of a growth inhibitor that will be studied and characterized further.

98 CRUST COMPOSITION ON LEAVES OF THREE SUBMERGED ANGIOSPERMS

Y. Waisel, (Tel Aviv University, Israel) and A. Stahel and J. Oertli, (E.T.H., Zurich, Switzerland).

Photosynthesizing leaves of Egeria densa, Potamogeton crispus and Myriophyllum spicatum, cause substantial alkalization of the ambient water. Net alkalization rates for Egeria, Potamogeton, and Myriophyllum were 0.7, 1.9 and 0.2 meq. base. g DW^{-1}. min^{-1}, respectively. The resulting high pH around the leaves, and the presence of proper concentrations of Ca^{2+} and Mg^{2+}, have induced the precipitation of crusts on the alkaline surfaces of those leaves. Those crusts differ in constitution. Calcite comprises the main constituent of the crust of Egeria whereas the crusts of Potamogeton and Myriophyllum include calcite, high-Mg calcite, and aragonite. Depending on the P concentration of the medium, the crusts have inclusions of

apatite. As calcite is precipitated when the Mg/Ca ratio is below 2, and aragonite is precipitated when the Mg/Ca ratio in the water is above 7, it is suggested that differences in Mg metabolism of those plants should be a major factor in determination of the crust characteristics.

99 ACUTE TOXICITY OF PLANT GROWTH REGULATORS USING IN VITRO CULTURES OF MYRIOPHYLLUM SPICATUM

Kimon T. Bird and Susan V. Christopher, Center for Marine Science and Research, University of North Carolina at Wilmington, Wilmington, North Carolina 28403.

In vitro cultures of the aquatic plant, Myriophyllum spicatum L. were used to determine the effects of plant growth regulators on growth and development. The in vitro culture medium consisted of Murashige and Skoog mineral salts, 3% sucrose, MS vitamins, and 2 mg/l 2iP (Kane and Gilman, 1991). Three different herbicides and a leaf defoliant were evaluated for their effects on development of Myriophyllum spicatum. These "plant growth regulators" were 2,4-dichlorophenoxyacetic acid (2,4-D), atrazine, glyphosate, and thidiazuron. Explants for the experiments were 3 nodal, unbranched segments of axenic Myriophyllum spicatum stock cultures, with the foliar portions of the middle node excised. The developmental parameters were production of new axillary buds, leaves, branches, and roots. Of these parameters, production of new branches was the most sensitive and reliable measure. The plant growth regulator 2,4-D had the greatest effects on development of branches at concentrations as low as 0.04 mg/l, followed by glyphosate (effects at 1 mg/l), atrazine (effects at 10 mg/l), and thidiazuron (effects at 20 mg/l). These assays could be completed in 5 days.

100 GROWTH REGULATOR EFFECTS ON IN VITRO SHOOT REGENERATION OF CRASSULA HELMSII

Michael E. Kane, Nancy L. Philman and Carolyn A. Bartuska, Department of Environmental Horticulture, University of Florida, Gainesville, Florida 32611.

Crassula helmsii (Swamp Stonecrop), an exotic aquatic angiosperm with high vegetative reproductive potential, has become established in Britain and Europe and has expanded its distribution over the last 20 years. The capacity of this species to regenerate from tissues with pre-existing buds (shoot tips and nodal segments) and via adventitious shoot formation from tissues without pre-existing buds (internode and leaf segments) was evaluated following in vitro culture in the absence and presence of the cytokinins (O - 25 μM), benzyladenine (BA), zeatin or (2-isopentenyl) adenine (2iP), and the auxin (1.0 μM) α-naphthaleneacetic acid (NAA). Maximum shoot regeneration occurred from shoot tips cultured in liquid medium consisting of full-strength Murashige & Skoog mineral salts (MS) supplemented with 2.0% sucrose for 28 days. Internode segments developed adventitious shoots when cultured on agar-solidified MS without growth regulator supplementation. Adventitious shoot development was enhanced on internode and leaf blade segments cultured in the presence of cytokinin and NAA. Benzyladenine and 2iP were the most effective promoters of adventitious shoot formation from leaf and internode segments in vitro, respectively. These results suggest that the spread of this plant in situ may also occur via adventitious shoot regeneration from fragmented stem segments.

101 CLEVER ALIENS

Kathleen H. Bowmer, G. McCorkelle and G.R. Sainty, CSIRO Division of Water Resources, Griffith NSW 2680, Australia.

Three alien aquatic plants (Alternanthera philoxeroides, Ludwigia peruviana, and Elodea canadensis) are highly successful invaders of aquatic and semi-aquatic habitats in south-eastern Australia, with quite

different strategies for survival and dispersal. Prospects for management are reviewed including the use of herbicides, mechanical methods (burning, draining, and drying), and competition with other species.

102 AQUATIC PLANT COMMUNITY RESPONSE (PERCENT COMPOSITION AND BIOMASS ESTIMATES) TO THE 1990 EXTREME DRAWDOWN, MUCK REMOVAL AND DISCING PROJECT ON EAST LAKE TOHOPEKALIGA, FLORIDA

Mikel W. Hulon, Edwin J. Moyer, Robert S. Butler and Robert W. Hujik, State of Florida Game and Freshwater Fish Commission, Division of Fisheries, 390 West Carroll Street, Kissimmee, Florida 34741.

Organic build-up of detrital plant material has accumulated in shallow littoral areas of East Lake Tohopekaliga, creating a low water berm and isolating hundreds of hectares of productive fish and wildlife habitat. A habitat restoration project which included extreme drawdown, mechanical muck removal, burning, and discing was completed in the spring of 1990. Vegetation transects were established to document changes in aquatic plant communities. Data was collected (percent composition and biomass) during October of 1989, 1990, and 1991 at seven sites on muck removal, discing, and control areas. Plant species shifted dominance at muck removal sites during the study and biomass estimates decreased as much as 99 percent. Discing could be beneficial under a variety of flooding and drying cycles and deserves further evaluation.

103 LIME ADDITIONS IN THE CONTROL OF AQUATIC MACROPHYTE GROWTH IN HARDWATER LAKES

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Lime additions to hardwater lakes and ponds are currently under investigation as a non-toxic means of controlling algal blooms in the hardwater lakes of central Canada. Whole-lake studies in which lime ($Ca(OH)_2$ and/or $CaCO_3$) was applied at dosages of 10 to 250 mg/l to three lakes and more than eight ponds showed that chlorophyll a concentrations were reduced by at least 50% for two or more years. Concurrent studies on aquatic macrophyte growth in four of the waterbodies showed that macrophyte biomass decreased by more than 90% from pretreatment values of 20 to 320 g/m^2 DW and remained at that level for two to three years post-treatment. The aim of this study was to determine the mechanism by which lime additions inhibit aquatic macrophyte growth and assess whether this technique could be developed for the control of aquatic macrophyte growth in hardwater lakes. Controlled experiments were undertaken in which $CaCo_3$, $Ca(OH)_2$ and a 1:1 mixture was applied at dosages of 100, 200 and 400 mg/l to 140 l tanks containing known biomass of Lemna trisulca, Myriophyllum exalbescens, Potamogeton pectinatus, and Potamogeton richardsonii growing in natural lake water and sediments. Biomass was reduced by at least 75% for mature plants (i.e. plants reaching the water surface) treated with higher dosages of $Ca(OH)_2$ or mixed lime as compared with untreated controls. Immature plants (i.e. < 0.15-0.25 m tall) were marginally affected by lime treatment. Measurements of water and sediment chemistry showed that higher dosages of $Ca(OH)_2$ caused a short-term (<2 wk) increase in open-water pH (from 8.6 to 10.5) and decrease in porewater soluble reactive phosphorus concentrations. Our results indicate, first, that lime additions to hardwater lakes inhibit aquatic macrophyte growth likely as a result of changes in carbon and phosphorus availability and, secondly, that lime is an effective, inexpensive, and non-toxic method for controlling algal and aquatic macrophyte growth in the hardwater lakes and ponds of central Canada.

104 HARBOR REGIONAL PARK-MACHADO LAKE BULRUSH HARVEST/MOSQUITO CONTROL PROJECT

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Machado Lake is an approximately 40 acre freshwater, eutrophic lake and major stormwater retention basin located within the City of Los Angeles, and is a recognized ecologically significant resource because of the valuable wildlife and fisheries habitat it provides. Symptomatic of the eutrophic condition of the lake is the presence of approximately 11 acres of a dense mass of emergent vegetation, predominantly bulrush, within the northeasterly arm of the lake. Excess mosquito production is a prevalent problem. The widespread and dense stands of bulrush, interspersed with large surface/subsurface mats of dead and decaying vegetation, create stagnant isolated pools and other mosquito producing habitat that is virtually inaccessible to mosquito fish and other invertebrate predators. The specific objectives are to harvest and dispose of 6-7 acres of dense bulrush growth to create a 60:40 percent interspersion of open water and emergent vegetation. The remaining 4-5 acres of bulrush will be patterned into a chain of islands. This approach will promote habitat for waterfowl and other bird life. The project began in February 1992 and will be completed within three months. Mechanical removal methods will be utilized and the results and conclusions will be presented at the symposium.

105 THE CONTROL OF ALGAE BY DECOMPOSING BARLEY STRAW

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Controlled laboratory experiments and over fifty field trials in lakes, reservoirs, drainage channels, canals, and ponds have shown that decomposing barley straw inhibits the growth of a wide range of algal species including Cladophora glomerata, Vaucheria dichotoma, Hydrodictyon reticulatum and Microcystis aeruginosa. The production of anti-algal factors is associated with aerobic microbial decomposition of straw, but does not appear to depend on the presence of specific microorganisms. In laboratory trials, algal growth is inhibited by up to 95% with as little as 2.4 g dry weight straw per cubic metre of water. The production of an inhibitory factor and how the effect is expressed in laboratory algal cultures, will be discussed. Some preliminary chemical analysis will also be presented.

106 POSSIBILITIES OF UTILIZING AN EXOTIC WEED LANTANA CAMARA TO CONTROL THE GROWTH OF WATER HYACINTH

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Biological control through plants is a recent phenomenon in which production of selective phytotoxins by plants has been used with some success. Allelopathy plays an important role in controlling plant growth through secretion, exudation, and leaching of toxic substances. This paper presents the possibilities of utilizing an exotic terrestrial weed Lantana camara (Verbenaceae) to control the growth of water hyacinth. This plant grows abundantly with a number of flower colours viz. red, prickly orange, yellow, pink violet and white in all parts of the world. A series of growth experiments on water hyacinth using sterilized soil and tap water show that leachates and water extracts of fresh, dried or decaying plants of Lantana kill the former completely within a few days. They inhibit the growth even in low concentrations. These results indicate the bio-control potential of Lantana. To date only Neochetina is known as an effective bio-control agent of waterhyacinth. In this respect, this study provides feasible opportunity to utilize terrestrial allelopathic species as bio-control measures against the growth of water hyacinth and other free-floating weeds.

107 AQUATIC WEEDS AND THEIR EFFECT ON THE HYDRAULIC EFFICIENCY OF OPEN CHANNELS

Fakhry Khattab, Water Research Center, 22 El Galaa St., Boulak, Cairo, Egypt.

In Egypt more than 29,000 km of the canals and drains are infested by all types of aquatic weeds. The presence of such weeds has increased the roughness of the channels boundaries and consequently seriously reduced the hydraulic efficiency. Field studies were carried out by the Research Institute of Weed Control and Channel Maintenance to determine the effect of floating, submerged, ditchbank, and emergent weeds on channel roughness. Results showed that in channels infested by Eichhornia crassipes, Manning's roughness coefficient is increased up to 0.065 while in the case of submerged weeds (Potamogeton spp., and Ceratophyllum demersum) this value has reached 0.04. Both ditchbank and emerged weeds have not affected the roughness much. In the case of no weeds, Manning's coefficient never exceeds 0.025. To improve the hydraulic efficiency of the irrigation system, an integrated programme of weed control is carried out annually by the Ministry of Public Works and Water Resources using combined mechanical, chemical, and biological methods, until the end of 1990, while in 1991 chemical control was stopped due to environmental reasons.

108 WEED AND SILT CONTROL IN MOSQUITO DITCHES

Jonas Stewart, East Volusia Mosquito Control District, 1600 Aviation Center Parkway, Daytona Beach, Florida

The East Volusia Mosquito Control District maintains 140 miles of ditches for mosquito control. These ditches are found throughout the Daytona Beach and New Smyrna areas of Volusia County. Excavators, mowers, herbicide sprayers, and hand tools are used to control weed growth and silt that contribute to mosquito production and drainage problems. A customized amphibious rotary ditcher has been used to construct shallow ditches and remove weeds and silt in marsh ditches. This unique ditcher can sling ditch spoil up to 100 feet on both sides of the ditch.

109 ROOT SYSTEM CHARACTERISTICS IN SYMPATRIC FLOATING-LEAVED MACROPHYTES, NYMPHAEA TETRAGONA GEORGI AND BRASENIA SCHREBERI J.F. GMEL

Hidenobu Kunii, Department of Biology, Faculty of Science, Shimane University, Matsue 690, Japan.

The underground parts of perennial floating-leaved macrophytes cannot be ignored, because they form a large part of the biomass and play an important role in the population dynamics. However, because of observational difficulties, little information is available on the behavior and biomass production of the underground parts of aquatic macrophytes except helophytes. The objective of the present study is to clarify the root system characteristics of two floating-leaved macrophytes, Nymphaea tetragona Georgi and Brasenia schreberi J.F. Gmel., which often occur together in acidic ponds in the locality. The quantitative observations under field and semi-natural conditions over 5 years have shown that biomass turnover ratios of the underground parts in both species are much higher than those expected. While the individual tuberous rhizomes in N. tetragona never branch nor proliferate and persist for a long time at the restricted site, the runners in B. schreberi perform short-distance dispersal and their life expectancies are short. Ecological significance of root system persistence will be discussed in terms of life history strategies of these two sympatric species.

110 GROWTH AND ALLOCATION PATTERNS IN A DEVELOPING MAT OF WATERHYACINTH (EICHHORNIA CRASSIPES)

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The development of waterhyacinth mats was examined to determine growth rates and allocation patterns during different growth stages and seasons. Waterhyacinth was grown in 1 m^2 rings that were sampled at staggered intervals after initiating the experiment early (May), middle (July), and late (September) in the growing season. Experimental ponds were maintained at a low pH, and one pond was amended with 11.4 kg nitrogen per week. Plants were separated into constituent parts after sampling, and analyzed for biomass, tissue nutrients, and carbohydrates. Early in development, plants allocated most production to root material, with little increase in average plant size. Once a critical density is reached, plants increase in average weight and production is reduced, but average plant size increases rapidly, resulting in subsequent adult plant mortality. Waterhyacinth exhibits a positive density dependent growth pattern early in development, plants allocate most production to root material, with little increase in average plant size. Once a critical density is reached, plants increase in average weight and production of daughter plants, with reduced allocation to roots. At peak density, daughter plant production is reduced, but average plant size increases rapidly, resulting in subsequent adult plant mortality. Waterhyacinth exhibits a positive density dependent growth pattern early in development, switching to the negative density dependent pattern more typical of plants after peak density is achieved.

111 GROWTH RESPONSES OF ALLIGATOR WEED TO TEMPERATURE AND PHOTOPERIOD

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At the beginning of winter, dormant plants of alligator weed Alternanthera philoxeroides (Martius) Grisebach, which had been established in free-draining 201 buckets for 15 months, were placed in heated glasshouses. Temperature minima of 10°, 15° and 20°C were maintained and combined with natural daylength and a 16 h photoperiod of natural day supplemented with low intensity light. Other factors were non-limiting. Both stem length and leaf expansion were promoted by increase in both temperature and photoperiod, as was node number to a lesser extent. Growth at 16 h photoperiod was erect and contrasted with prostrate growth under natural daylength. Total leaf areas per plant and total top dry weight were increased by increase in temperature and photoperiod especially during the first few weeks of treatment, differences thereafter remaining fairly constant. Overall, while vegetative growth was least at 10°C, differences between 15° and 20°C minima were smaller. Flowering was markedly promoted by a 16 h photoperiod and is probably a normal stage in the developmental cycle before senescence. These results have significance both for the effective timing of herbicidal sprays and for predicting those geographical areas where alligator weed may be a potentially serious problem.

112 NUTRIENT COMPOSITION OF TWO EMERGENT AQUATIC PLANTS

Anjana Dewanji and Shyam Matai, Biological Sciences Division, Indian Statistical Institute, 203, B.T. Road, Calcutta - 700 035, India.

The present investigation was undertaken to explore the nutrient composition of two emergent aquatic plants as a means of utilizing large quantities of harvested plant materials which create problems of disposal. A natural stand of Allmania nodiflora and Ipomoea reptans, two edible plants which grow profusely in ponds and ditches all over the country, was studied over a nine month period to popularise its potential as a food resource.

The mean standing crop fresh yield of A. nodiflora was 1545 g/m^2 while that of I. reptans was 1125

g/m^2. Both plants had a high nitrogen content over all seasons (2.67 to 4.93% in A. nodiflora and 2.62 to 5.07% in I. reptans) and were a good source of beta-carotene as well (4.7 to 5.3 mg/100g in both plants). When compared to other commonly used green leafy vegetables, both plants had comparable levels of mineral constituents. Although, I. reptans was more stable in nutrient compositions over all harvesting seasons, never-the-less the widespread consumption of both plants should be promoted as a cheap source of nutritious greens.

113 VARIATION IN NUTRIENT LIMITATION AND STORAGE CAPACITY OF MARINE ALGAE REPRESENTING DIFFERENT GROWTH FORMS

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In situ fertilization experiments were conducted during 1991 in a Danish estuary to establish the variability and temporal extent of nutrient limitation of algae representing different growth forms. Nutrient limitation was evaluated from biomass or growth-rate responses following N and P fertilization. The phytoplankton community and the ephemeral green algae Ulva lactuca were limited during most of the year. The filamentous algae Ceramium rubrum was limited by N during a short summer period, while slow growing Fuscus vesicolosus did not respond to fertilization at all. Phosphorus limitation was not documented.

Tissue concentrations of N and P were highly variable for all macroalgae, with maximum values in winter, and minimum values reached during summer. Maximum concentrations were almost identical among species. Phytoplankton nutrient concentrations did not vary significantly during the period, but N:P ratios indicated that phytoplankton was N limited. I conclude that the nutrient storage capacity is invariant among species and that more extensive nutrient limitation is the result of high growth rates in species with thin thalli leading to depletion of internal N concentrations.

114 QUALITATIVE AND QUANTITATIVE CHANGES IN NITROGEN DURING SPROUTING OF HYDRILLA TURIONS

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Subterranean turions (tubers) are the principal means by which hydrilla infestations persist. A study of the sprouting process of turions was undertaken to determine possible control points. Turions of the monoecious and dioecious biotypes of hydrilla from the U.S. were allowed to sprout in a defined soil mix under a 12 h photoperiod. Samples were taken on day 0, 21, and 35. Plants were cut back to the hydrosoil on day 35 and further samples were taken on day 49 and 63. Dry weights of turions, roots, shoots, and leaves were recorded. Plant parts were analyzed for total carbon and nitrogen. Free amino acids and soluble proteins were determined in extracts from the material as well. Nitrate reductase activity was determined by the ability of intact tissue to reduce nitrate to nitrite in the presence of 0.2% isopropanol in the dark in vacuo. Some samples were taken for microscopy as well. During sprouting, there was a slight decrease in the total biomass of the developing plant plus residual turion. On day 35, the total dry weights, of monoecious and dioecious plants were 96 and 91% of the initial dry weights, respectively. However, the total amount of nitrogen associated with the developing plant plus residual turion increased greatly during this period. Monoecious plants on day 35 had 257% of the amount of nitrogen as on day 0, while dioecious plants had 182%. Nitrate reductase activity was detectable in turions but not leaves and shoots of 19 day old monoecious plants. Although only 8% and 18% of the total nitrogen associated with the plant was found in the monoecious and dioecious turions, respectively, at the time of harvest on day 35, both plants were able to regrow vigorously. Nitrate assimilation through the subsoil portion of the plant is important to the early growth of hydrilla. Nitrogen reserves in the turion can be utilized if the developing plant is removed, but otherwise seem to be spared.

115 DEEP WATER AQUATIC PLANT COMMUNITIES IN AN OLIGOTROPHIC LAKE: PHYSIOLOGICAL RESPONSES TO A VARIABLE LIGHT CLIMATE

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The littoral zone of oligotrophic Lake Waikaremoana, New Zealand, is dominated by native aquatic plants, and extends to a depth of 15 m below mean lake level. The bottom boundary (at 15 m relative to mean lake level) remained constant throughout the year in spite of large seasonal changes in solar radiation and a variation in lake level of up to 3 m. There was evidence that the deep water community consisting of Chara corallina had adapted physiologically to low light conditions. Net photosynthesis (CO_2 exchange) was reduced to 3 μg C (μg Chl a) h^{-1} at the lower boundary, half of that recorded at 4 m. The concentration of chlorophyll a was, however, considerably greater at the lower boundary than higher in the profile (ca. 7 mg Chl a (g dry wt)$^{-1}$ at 15 m vs 4 mg Chl a (g dry wt)$^{-1}$ at 4 m). There was no trend in the ratio of chlorophyll a and b with increasing depth. I_k of the community at the lower boundary was only 75 μmol $m^{-2}s^{-1}$. The littoral community is therefore not greatly affected by the lake level changes caused by "normal" hydro-electric operations, but will be influenced by major long-term changes to level or PAR attenuation.

116 THE ROLE OF MACROPHYTES IN HEAVY METAL CIRCULATION IN SHALLOW COASTAL AREAS

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The aim was to investigate the influence of macrophytes on heavy metal circulation in shallow coastal areas with heavy metal contaminated sediment. Studies on the uptake and content of Cd, Cu, and Zn by roots and shoots of macrophytes (especially of Potamogeton pectinatus) in water and sediment, respectively, were made both in the field and laboratory. Uptake by roots was not as effective as the uptake by shoots, e.g. uptake of Cd by roots was 20-50% of that in shoots. The transport from roots to shoots was greater than the transport in opposite direction, e.g. ≈ 30% of the Cd taken up by roots is transported to the shoots, while ≈ 9% of Cd taken up by shoots is transported to the roots. Metal transport from shoots to rhizomes was also found. Thus plants are able to take up metals both from water and sediment. The amount of heavy metal taken up depends on factors like salinity, organic matter, pH etc. Uptake, transport, and extrusion of heavy metals by plants are discussed in relation to water and sediment characteristics. Thus it may be concluded that macrophytes play an important role for heavy metal circulation in shallow coastal areas.

117 STRATEGY ANALYSIS OF EUHYDROPHYTE COMMUNITIES IN EUROPEAN RIVERINE WETLANDS

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The study examines the ecology and survival strategies of euhydrophyte populations in the open waters of riverine wetlands in Europe. It assesses the value of a strategy-based approach as a framework for understanding and predicting the responses of wetland euhydrophyte communities to anthropogenic perturbation. The project rationale is outlined, and information provided on environmental attributes of, and anthropogenic impacts affecting each of six target wetland sites. These are located to cover a range of the climatic and environmental conditions prevailing in Europe: from cool, wet oceanic conditions in Ireland and Scotland, to progressively drier and hotter conditions in southern England, France, and Spain. Initial results are summarised, and an outline presented of current knowledge of the survival strategies of the euhydrophyte species present in the target wetland areas.

118 U.S. ARMY CORPS OF ENGINEERS ENVIRONMENTAL RESOURCES RESEARCH AND ASSISTANCE PROGRAMS

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The U.S. Army Corps of Engineers Environmental Resources Research and Assistance Programs (ERRAP) is a management function within the Environmental Laboratory of the Waterways Experiment Station, Vicksburg, Mississippi. The ERRAP office has the responsibility of program management, technology transfer, and public information for the Corps of Engineers' Aquatic Plant Control Research Program (APCRP), Natural Resources Research Program (CRRP), and Water Quality Research Program (WQRP).

The APCRP is a comprehensive program developing technology for biological, chemical, and integrated control methods as well as examining the ecology of problem aquatic plants, and developing simulation models of proven control techniques. Current biological control research involves the use of both insects and pathogens to manage hydrilla and Eurasian watermilfoil. Chemical control research is directed toward improving the control of problem submersed plants in high water exchange environments using herbicides and plant growth regulators. Research in the ecological area is directed at determining the response of submersed plants to environmental factors and investigating the interactions among environmental factors and submersed plants. The simulation technology area develops PC-based simulation models of available biological and chemical control techniques as well as developing plant growth models for waterhyacinth, hydrilla, Eurasian watermilfoil, and waterlettuce. In addition to the APCRP, the NRRP is developing technology to provide the opportunities for recreation and the management of natural resources at Corps projects, and the WQRP is involved with developing technology for solving water quality problems associated with Corps reservoir and waterway projects.

119 EVALUATION OF AN INTERSTITIAL WATER SAMPLER FOR ANALYSIS OF NUTRIENTS IN CONTAINERS USED FOR CULTURE OF HYDRILLA

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Studies were conducted with air diffuser stones to evaluate their potential for determining interstitial nutrients in a sand rooting media amended with controlled release fertilizers for cultures of dioecious hydrilla (Hydrilla verticillata (L.f.) Royle) in out-door concrete tanks filled with flowing pond water. Investigations were conducted on the placement of stone relative to the fertilizer layer in containers (dimensions of 10 cm in diameter by 25 cm in height) filled with sand. Air diffuser stones constructed of silica glass were found to be superior to crushed rock stones, exhibiting less interferences and easier maintenance. Placement of stones was critical in determining nutrient concentrations. Optimum measurements of nutrient concentrations were achieved when the stone was centrally located below the layer of fertilizer. Analysis of water samples above the sand layer indicated relatively little upward leaching of nutrients when the layer of fertilizer was placed 7.6 cm below the surface of the sand. Visual observations of hydrilla plant roots indicate they grow in very close proximity to the layer of fertilizer.

120 GENETIC VARIATION IN THE FRESHWATER ANGIOSPERM MYRIOPHYLLUM ALTERNIFLORUM DC

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The degree of genetic variation within and between populations of Myriophyllum alterniflorum was determined by gel-electrophoresis of 273 plants from 13 populations after growth under standard conditions. Of the 12 enzymes studied, 8 were polymorphic. The plants showed a high degree of variation; 58 multi-enzyme phenotypes based on 5 enzymes were distinguished. Twenty (35%) of these phenotypes were represented by one individual and 36 (62%) were restricted to one site. No population was encountered with a single multi-enzyme phenotype. Cluster-analysis of single-and-multi-enzyme phenotypes revealed four clusters but these were not correlated with presence in a watershed, geographic distance, or alkalinity. For 2 loci where analysis was possible, the majority of the populations were in Hardy-Weinberg equilibrium which suggests that sexual reproduction is common and that it occurs via random mating. Calculations for these loci using Wright's F statistics revealed that panmixia was not occurring largely because of genetic subdivisions between populations rather than inbreeding within populations. The possible reasons for the high genetic variation uncovered is discussed.

121 THE ECOLOGY OF THE EXOTIC AQUATIC PLANT TRAPA NATANS INCLUDING GROWTH HABITS AND SEED PRODUCTION

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Trapa natans, a freshwater, floating leaf annual native to Eurasia and introduced into New York State several decades ago, continues to enlarge its range across the northeast. Major infestations now exist along the shoreline of the Hudson and Mohawk Rivers, Lake Champlain, and numerous lakes and ponds. A study has been initiated in the Watervliet Reservoir to study phenology and biomass production. The life cycle is characterized with a peak biomass of 758 g/m^2 occurring in late August. Impact of cutting on flowering and seed production was studied to evaluate efficacy of air boat cutting as a possible control measure. The seed bank was measured by the removal of sediment cores from treatment (cut) and control (uncut) sites after germination (June) and then senescence (November) of that year's cohort. A fairly even distribution of seeds had been built up over years of unchecked growth (70 seeds/m^2 treatment site versus 80 seeds/m^2 for the control site). However, in treatment sites new deposition of seeds was reduced in two years to 20 seeds/m^2 versus 170 seeds/m^2 in control areas. Seed fall collection baskets were utilized to examine new seed deposition in control sites. Results revealed new deposition of 161 seeds/m^2, correlating well with the core data.

122 A PHYSIOLOGICAL BASIS FOR THE DISTRIBUTION OF AQUATIC PLANTS IN FLORIDA

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Four species of freshwater rooted submersed macrophytes (Hydrilla verticillata (L.f.) Royle (monoecious and dioecious biotypes); Egeria densa Planch.; Myriophyllum spicatum L.) are being investigated to discern factors affecting their distribution in Florida. Distribution maps show that E. densa and M. spicatum are limited to the cooler (especially in summer), spring fed waterways. Physiological data suggest that the dioecious H. verticillata in Florida is photosynthetically more efficient in warmer waters when the potential for carbon limitation is greater. The greater efficiency is due to its ability to alter

photosynthetic metabolism from C_3-like and C_4-like. This ability appears to give H. verticillata a competitive edge allowing it to out compete E. densa and M. spicatum in the majority of Florida's lakes and rivers. The monoecious H. verticillata (not currently found in Florida) is considered to be one of the major potential weed threats. Physiological data suggests that the monoecious form may compete successfully with the dioecious form already present in Florida.

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123 CARBONIC ANHYDRASE ACTIVITY IN PHOTOSYSTEM-DEFICIENT MUTANTS OF CHLAMYDOMONAS REINHARDII

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Activity of carbonic anhydrase (CA) was studied in wild type Chlamydomonas reinhardii and five mutants distinguished only by retaining PSI, PSII, light-harvesting antennae. Two forms of CA, soluble (sCA) and membrane-bound (mbCA), were found in the cells. The highest activity of mbCA was observed in mutants which retained both photosystems, as well as in those with only PSI and, to a less extent, in those with PSII. The mutants deprived of photosystems but retaining light-harvesting complexes, almost lacked mbCA. It is concluded that there is a correlation between the retention of mbCA and mutant abilities to perform photosynthesis. The role of mbCA in inorganic carbon concentrating system of microalgae are discussed.

124 CHEMICAL ECOLOGY OF POTAMOGETON PECTINATUS L.

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Potamogeton pectinatus is characterized among other species of this genus by high tolerance to water contamination. Potamogeton pectinatus populations are ecologically different and are conditioned by water chemistry. They differ with respect to individual, group features and macroelement and microelement contents. Various values of these features show optimum habitat conditions of Potamogeton pectinatus. In individual and group features of this species appear all aspects of human life (anthropogenic factor). They may be utilized as bioindicators of water contamination and also need to be evaluated for biomass production.

125 AEROBIC BIOFERMENTATION AND VERMICOMPOSTING OF HARVESTED AQUATIC PLANTS FROM LAKES

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A primary advantage of mechanically harvesting nuisance aquatic macrophytes, rather than employing herbicides, is that removal of macrophyte biomass also removes substantial stores of nutrients from lakes. These programs, however, have frequently been forsaken because of high costs and the lack of economically acceptable disposal sites for harvested plants. This study examined the potential use of composting for solving disposal problems and producing a product that could offset the higher costs of mechanical harvesting programs.

The aerobic biofermentation of aquatic plant biomass was examined in five trials using water hyacinths with various formulations of secondary ingredients. The vermicomposting (composting using earthworms) of water hyacinths was examined using plants from an 8-acre water hyacinth farm. Both

aerobic biofermentation and vermicomposting were successful in transforming harvested water hyacinths into organic fertilizer and worm castings, thereby providing acceptable disposal of harvested plant biomass. These products have potential salability in the home gardening and agriculture markets as soil and fertilizer amendments. Although mechanical harvesting programs have higher costs than herbicide programs, they serve a dual function in both aquatic plant management and water quality management through in-lake nutrient reduction. The addition of composting income to mechanical harvesting programs make this alternative even more attractive.

126 INTERNAL CO_2 TRANSPORT AND PHOTOSYNTHESIS IN THE EMERGENT AQUATIC MACROPHYTES SCIRPUS LACUSTRIS AND CYPERUS PAPYRUS

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In this work we investigated whether sediment-derived CO_2 could be accumulated and transported through aerenchymatic stems of emergent aquatic macrophytes, and if such CO_2 could be utilized for photosynthesis of these stems. Two species with different photosynthetic responses to CO_2 were chosen: Scirpus lacustris, a C_3 plant found to saturate its photosynthesis at slightly above ambient CO_2 concentrations and with a CO_2 compensation point of ca. 100 ppm, and Cyperus papyrus, a C_4 plant showing CO_2 saturation already at ca. 220 ppm and with a compensation point at ca. 15 ppm CO_2. (These two species can be found growing naturally in the same habitat in Israel.) Aerenchymal CO_2 concentrations were ca. 50,000 ppm at the base of the stems and decreased drastically upwards, but were always higher than the ambient CO_2 level (especially in Cyperus papyrus). No clear diurnal pattern in internal CO_2 levels could be established. The contribution of aerenchymal CO_2 for the net photosynthetic rates of these plants (which photosynthesize mainly by their green stems) will be discussed in relation to their different photosynthetic responses to ambient air.

127 ASSESSING THE POTENTIAL OF SEDIMENTS FOR SUPPORTING THE GROWTH OF ROOTED, SUBMERSED AQUATIC PLANTS

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The potential of experimental pond sediments to support the growth of rooted, submersed aquatic plants was evaluated in a greenhouse bioassay experiment. The experiment was conducted in fiberglass tanks containing an experimental culture solution lacking nitrogen (N) and phosphorus (P). Under these conditions plant growth in the assay was dependent on sediment supplies of these elements. The test species, Hydrilla verticillata, was grown for 5 weeks on 12 different pond sediments and a reference lake sediment of known growth potential. Growth of hydrilla on the different sediments was highly variable, exhibiting greater than a 6-fold range in biomass accumulation. Growth on all but one of the sediments was low relative to that obtained on the reference sediment. To evaluate possible nutrient limitation, hydrilla was also grown on a composite pond sediment with and without the addition of N and P. Growth was responsive to additions of N but not P, indicating N limitation of plant growth on the composite sediment. Further evaluation of the results revealed a strong first-order relationship between growth on all sediments and the level of NH_4-N in the sediment. The observed differences in growth potential of the pond sediments were thus attributable to differences in sediment N availability. These findings were subsequently verified in a pond experiment, where the growth of hydrilla was found to be limited by N. These results demonstrate the utility of the sediment bioassay technique for predicting the potential of bottom sediments to support the growth of rooted, submersed aquatic plants.

128 APPLICATIONS OF SIMULATION PROCEDURES IN AQUATIC PLANT MANAGEMENT

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Personal computer based simulation procedures are being developed to assist in the transfer of information on control technologies developed under the US Army Corps of Engineers Aquatic Plant Control Research Program (APCRP). Plant growth simulation procedures provide daily updates for plant biomass through consideration of the effects of site conditions on important plant growth processes. Currently, simulations are available for waterhyacinth, hydrilla, and Eurasian watermilfoil. Simulation procedures for operational control techniques have been developed for mechanical harvesting systems, three biocontrol agents and several aquatic herbicide formulations. Outputs from these simulation procedures provide information that aquatic plant managers can use to answer "What if" types of questions regarding seasonal levels of aquatic plant growth and effectiveness of proposed control strategies. Example applications which use this type information will be provided through poster presentation.

129 NITROGEN FIXING AQUATIC PLANT AZOLLA SP. HYBRID AS A BIOFERTILIZER FOR RICE CROPS

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Azolla is a free floating aquatic fern that floats in water and fixes atmospheric nitrogen in association with nitrogen fixing blue green alga - Anabaena azollae. Azolla is a low cost biofertilizer which can contribute 40-60 kg N ha^{-1}. The relative growth rate is very high and it doubles its weight in a 2-3 day period. Because of its rapid growth Azolla produces good biomass in a short period. Within a 3-4 week period, Azolla can multiply and produce biomass ranging from 20-25 t ha^{-1}. The nitrogen content ranges from 3-6% on a dry weight basis which is relatively higher than other green manure plants. Azolla hybrid Rong Ping was tested as a biofertilizer for rice crops in wet season rice. Fertilizer nitrogen with the Azolla hybrid Rong Ping has increased the grain yield and yield components more than fertilizer nitrogen alone. Fertilizer nitrogen at 60 kg N ha^{-1} with the Azolla hybrid at 20 t ha^{-1} recorded higher grain yield. The Azolla hybrid with fertilizer nitrogen has recorded higher accumulation and uptake of nitrogen, phosphorus, and potassium.

130 ISOETID POPULATION DEMOGRAPHY OVER A DISTURBANCE GRADIENT

Jozef Szmeja, Department of Plant Ecology and Nature Protection, University of Gdansk, Czolgistow 46, Pl-81-378 Gdynia, Poland.

The results are presented of studies of the fecundity, growth rate, and life-span of Isoetes lacustris L., Lobelia dortmanna L. and Littorella uniflora L. Ascher., as well as of the reproductiveness and death rate of their populations over a gradient of physical disturbances caused by water waves. Over the disturbance gradient a decrease in the variation of individual size and fecundity, as well as increasing differences in the biomass expenditure on propagation can be seen. In disturbed habitats the size, fecundity, growth rate, reproductiveness, and survival rate of I. lacustris are lower than in undisturbed habitats. L. dortmanna populations' reproductiveness and mortality are higher in disturbed than in undisturbed habitats. This is the result of the generative offspring's being more numerous. Fecundity is in both cases similar. L. dortmanna population regeneration rate is faster in disturbed than in undisturbed habitats, because of a shorter maturation time of the vegets and changed numerical offspring proportions in the population. Differences

between L. dortmanna individuals with mycorrhiza and those without it are statistically insignificant. The ecological strategies of the isoetids differ: type S (I. lacustris), type SR (L. uniflora, L. dortmanna). Physical disturbances shorten the habitat time scale and accelerate abundance changes in the populations of the two species following the SR strategy, but decelerate them in the population of the species with the S strategy.

131 THE EFFECT OF SULPHIDE AND FERROUS IRON ON THE GROWTH OF POTAMOGETON PECTINATUS L

C. van Wijck, C.J. De Groot & P. Grillas. Station Biologique Tour du Valat 13200 Arles, France.

P. pectinatus is nitrogen limited on some Camargue sediments. However a low biomass produced when cultured on two sediments with high organic matter contents, could not be explained by a lack of available nitrogen. Considerable concentrations of sulphide or ferrous iron due to the anoxia of the sediment were suggested to be responsible for the low biomass production. An experiment showed that addition of iron or sulphide to sediment resulted in a reduced biomass production of P. pectinatus. A negative correlation between interstitial [NH_4^+] and the lower plant biomass has been found. However high tissue [N] suggests that nitrogen uptake does not limit plant growth. In habitats in which P. pectinatus was observed to be in a poor condition ferrous iron or sulphide were found in the interstitial water of the sediment. Toxic effects of sulphide and ferrous iron have been demonstrated for emergent and terrestrial macrophytes but not for submerged macrophytes. Tolerance of those toxic compounds may be an important ecological adaptation, which may influence the competition between different submerged and emergent macrophyte species and algae.

132 THE IMPACT OF TEMPERATURE ON THE DEVELOPMENT OF HYDRELLIA PAKISTANAE LIFE STAGES

Ramona H. Warren, USAE, Waterways Experiment Station, Vicksburg, Mississippi.

Hydrilla is an exotic aquatic plant introduced into the southeastern United States from the old world. Because of its persistent nature and vegetative reproduction, hydrilla is difficult to suppress by herbicides or other conventional methods. It interferes with water flow, fishing, swimming, and boating. Biological control using insects is a potential management tool. One such insect is a small fly from India, Hydrellia pakistanae. This insect's larvae mines the leaves of submersed hydrilla. This study was conducted to determine the effect of temperature on the developmental rate of the different life stages of Hydrellia pakistanae. Studies were conducted at 20, 25, and 27° C. Developmental rates were directly proportional to temperature. The highest rates of development were noted at 27° C and the lowest at 20° C. Percent survival was greater at 25° C. Twenty-five degrees Celsius appeared to be the best temperature for the growth of a Hydrellia population. Although developmental rate was higher at 27° C, the decreased survival would reduce the efficacy of colony growth.

133 PH-ASSOCIATED PLASTICITY AND LOCAL ADAPTATION IN THREE ISOETID-FORM AQUATIC PLANTS

Evan R. Weiher and Charles W. Boylen, Department of Biology and Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, New York 12180.

The distribution of isoetid-form aquatic plants is largely unaffected by pH and lake acidification; local adaptation to ecotypes is apparently a common adaptive feature of their success. Three species, Eriocaulon septangulare, Juncus pelocarpus f. submersus, and Lobelia dortmanna, were reciprocally transplanted among three Adirondack lakes exhibiting a pH/nutrient gradient (pH 5.3, 6.5, and 7.1).

Transplants were monitored for two growing seasons for morphological plasticity, survival, and reproduction to assess local adaptation and variable fitness. Significant ANOVA population and interaction effects suggest local adaptation in all species. Eriocaulon and Lobelia exhibited increased reproduction and biomass at higher pH conditions, while Juncus responded oppositely. pH-associated variation in fitness suggests phenotypic selection as a partial mechanism for the apparent ecotypic differentiation. Intraspecific variation may be an important, yet understudied, factor with respect to both the distribution of macrophytes and the effects of management on their distribution.

134 CHEMICAL COMPOSITION OF SUBMERSED AQUATIC VEGETATION, LAKE OKEECHOBEE, FLORIDA (1990)

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The chemical composition of submersed vegetation in Lake Okeechobee, Florida was determined from biomass samples collected along 60 transects. Biomass samples were partitioned into component taxa, dried, and analyzed for 10 major and minor elements by gas chromatography and spectrophotometric procedures. Macrophytes analyzed included Ceratophyllum sp., Chara sp., Hydrilla verticillata Royle, Najas guadalupensis (Spreng.) Magnus, Potamogeton illinoensis Merong, and Vallisneria americana Michx.; epiphyte samples analyzed included Lyngbya wollei (Farlow ex Gomont) Speziale and Dyck. Significant differences in chemical composition were identified for all genera using MANOVA ($p. \leq 0.05$). Major elements (on a percentage dry weight basis) were generally highest in Ceratophyllum, Hydrilla, or Najas.
This work was supported by a contract from South Florida Water Management District to University of Florida.

135 THE IMPACT OF MECHANICAL HARVESTING ON QUALITY OF WETLAND VEGETATION: A QUANTITATIVE APPROACH

Elly P.H. Best, DLO-Centre for Agrobiological Research, P.O. Box 14, 6700 AA Wageningen, The Netherlands.

A 3-year field experiment was carried out to investigate the effects of mechanical harvesting regimes on the species composition of ditch vegetation. Mechanical harvesting included 4 treatments, of which the last one served as control, being cutting in 1) May, 2) May and July, 3) May, July and August, and 4) November. The experimental design involved 5 successive blocks per site, with treatments randomized over blocks. The experiment included 6 sites, representing 3 soil types (sand, clay, and peat) and 3 water qualities (eutrophic freshwater and eutrophic brackish water). Morphometry and degree of exposure to sunlight (north-south orientation) were similar. The vegetation composition was recorded annually. Soil quality was measured 1 x 3 yr^{-1}, water quality 1 x $month^{-1}$. The data on vegetation composition and abiotic variables were analyzed using multivariate regression techniques (CANOCO) and the statistical package GENSTAT.

Mechanical harvesting affected the species composition of the vegetation significantly from the first experimental year onwards. Harvesting in spring usually allowed the highest species number on sand, but in November on peat. Soil and water quality were usually more important than mechanical harvesting in accounting for changes in species composition. For aquatic vegetation few (1-7) species proved persistent through harvesting. Harvesting in spring favoured submerged species with dormant organs, harvesting in November, however, emergent species. For shore vegetation more (2-21) species proved persistent through harvesting. In this case the tentative favouring of distinct plant groups was obscured by the mixing of terrestrial and marsh species in the shore vegetation.

136 VEGETATION ZONATION ALONG WATERCOURSES: THEIR MUTUAL RELATIONSHIPS AND IMPLICATIONS FOR MECHANICAL CONTROL

R. Pot, Advisory Group on Vegetation Management, IKC-NBLF, Bornsesteeg 69, 6708 PD Wageningen, The Netherlands.

The aim of this study was to find out how mechanical control affects the vegetation structure and species composition of watercourses. In terms of Braun-Blanquet vegetation types, the vegetation in and along watercourses shows a strong cross-sectional gradient. Submersed vegetation and bank vegetation have to be treated as different vegetation elements. In most cases a hydrosere of three to five or more vegetation types can be distinguished along watercourses that are only ten meters or less in width. Mechanical control measures take this zonation into account treating different zones differently.

Relevés were made in every vegetation zone in watercourses for which the management was well-documented. Classification of the relevés showed strong interference between adjacent zones within each watercourse. Both the species composition and the vegetation density was strongly related to that of the neighbouring zones, and influenced by the land use along the watercourses. Analyses of the between zones relationships clearly showed the nature of the relationships between control measures and vegetation development.

137 MECHANICAL HARVESTING REQUIREMENTS AND EVALUATION IN SOUTH FLORIDA FLOOD CONTROL CANALS

Steve Smith and Mike Bodle, South Florida Water Management District, West Palm Beach, Florida.

The canals in the South Florida Water Management District are unique in several ways. They must remain weed free in order to move flood water efficiently. The system also delivers potable water to coastal areas and the Everglades National Park. The canals are crossed by low bridges, contain abandoned cars and other discarded appliances. They serve as a sport fishery and recreational water, as well as habitat for the endangered West Indian manatee. Hydrilla has been a problem in many of these canals for 30 years. The District has controlled hydrilla by numerous means. Recently, the District has asked equipment manufacturers to design and test mechanical equipment for greater efficiency.

138 WATER HYACINTH MECHANICAL HARVESTING - LAKE CIDRA, PUERTO RICO PILOT PROJECT

Gerald N. Smith and Nancy S. Palmstrom, Aquatic Control Technology, Inc., Northborough, Massachusetts and Fugro-McClelland (East), Inc., Northborough, Massachusetts.

Water hyacinth covered 60 percent of Lake Cidra, a 263 acre public drinking water reservoir, in December 1991. Investigations revealed plant biomass of 164 - 428 tons/acre, often in excess of literature values. A mechanical removal system, consisting of a conventional harvester and transporter fitted with pusher bars, a hydro-rake, and two on-shore excavators were ultimately selected. Hyacinth mats, some in excess of 10,000 sq. ft. (73 tons), are broken off and pushed to shore. Containment booms are being used to prevent re-infestation from non-harvest buffer area, and confine material prior to removal by on-shore equipment. The excavators compress the plant material and load it to the trucks. Harvesters are also being used to remove small scattered infestations. Based upon preliminary data for this ongoing pilot project, the harvesting system removes more than 1 million pounds of biomass (168 truck loads) per 10 hour day. On average the system clears one acre of hyacinth per day, with a maximum of two acres reported to date. Productivity has been largely limited by the ability of on-shore equipment to remove the material. This system may have applications in other reservoirs and lakes where the alternative hyacinth controls may not be feasible.

139 DEVELOPMENT OF ADVANCED MECHANICAL HARVESTING EQUIPMENT

Harlan M. Stein and T. Amimoto, President, SR Group, Inc., Houston, Texas and General Manager, Mitsui Engineering & Shipbuilding Co., Ltd., Tokyo, Japan.

One objective of the SR Group, Inc. was to develop a harvester with a low profile and cutting depth of 10' for removing both surface and below surface aquatic plants. The cost of the unit had to be competitive, while productivity substantially exceeded conventional equipment. Based upon our experience in mechanical removal of aquatic plants in SE Asia, we evaluated the potential for cutting in south Florida canals; height limitations, depth of cut (canals), maneuverability, cutter configuration, and propulsion. A mechanical harvester was developed which requires one operator and can cut plants to a 10' depth. The productivity, at an average cutting depth of 7', is 1.5-2.0 acres/day with shore dumping, and a probable productivity of 4 acres/day using collector boats. The harvester met expectations and was demonstrated in extremely dense growths of hydrilla in south Florida canals. The harvester can be easily modified to meet a variety of needs.

140 THE SUCTION HARVESTING OF EURASIAN WATERMILFOIL AND ITS EFFECT ON SURROUNDING NATIVE PLANT COMMUNITIES

C.W. Boylen[1], R.T. Bombard[1], J.W. Sutherland[2] and L.W. Eichler[1], [1]Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, New York and Bolton Landing, New York and [2]New York State Department of Environmental Conservation, Water Research Section, Albany, New York.

As part of a nuisance aquatic plant control program targeted at Eurasian watermilfoil, six sites on Lake George, New York were selected for control by diver-operated suction harvester. Prior to suction harvesting, ten 0.1 m^2 biomass samples were collected from each site. Samples were randomized within the area to be harvested, sorted by species, dried and weighed. A grid system of 36 contiguous 1 m^2 quadrats was also located within each of the treatment areas. The species present and their relative percent cover in each quadrat were recorded prior to harvest, shortly after and one year post harvest. Results showed a substantial reduction in the biomass of milfoil at all sites as a result of suction harvesting. One year after harvest, the impacts of harvesting on the native plant community include greater species diversity and reduced density (biomass and percent cover) at a majority of the treated sites.

141 DISTRIBUTION OF HYDRILLA IN CHINA: IMPLICATIONS ON FUTURE SPREAD IN NORTH AMERICA

Dr. Joe Balciunas and Dr. Chen Ping Ping, USDA Australian Biological Control Laboratory, Kevin Stark Research Building, James Cook University, Townsville QLD 4811, AUSTRALIA and Sino-American Biological Control Laboratory, Chinese Academy of Agricultural Sciences, Beijing 100031, CHINA.

China is a massive country with a huge population, but the distribution of various aquatic weeds within it is poorly understood. In 1989, the U.S. Department of Agriculture, along with the Chinese Academy of Agricultural Sciences, formed the Sino-American Biological Control Laboratory (SABCL). One of the first, and still major, projects for SABCL has been aquatic weeds. While the Cultural Revolution (1966-1976) literally destroyed many scientific institutions and scientists, luckily, some herbarium specimens managed to survive. Inspection of these, along with the collecting trips made by ourselves, and other USDA and SABCL scientists, have greatly increased our understanding of the distribution of Hydrilla verticillata, and other aquatic weeds. Our collections of hydrilla in the northern provinces of China, indicate that this weed will most likely continue to expand in a northerly direction, from its present infestations in North America.

142 THE INFESTATION OF WATER HYACINTH IN CHAO PHRAYA RIVER BASIN

P. Benyasut and S. Benyasut, Weed Control and Research Branch, Royal Irrigation Department, Pakret Nonthaburi 11120, Thailand.

The Kingdom of Thailand located on the Indo-Chinese Peninsula of Southeast Asia, encompasses an area of 513-520 square kilometers. Thai economy depends on agriculture. Paddy rice, which is by far the most important crop, grows on about 75% of the total agricultural land in Chao Phraya river basin. There exist potential areas of about 1,160,000 ha. in wet season and about 500,000 ha. in dry season for irrigation development in the basin of Chao Phraya river. One problem in the irrigation system is the obstruction of water weeds in the irrigation canal and drainage canal. The infestation of water hyacinth has seriously obstructed the waterways. Anything that affects the water supply directly affects the economy of the nation. The ecosystem was changed because of the irrigation development which was conducted since 1910. Since then the waterways, water level, and water flow in Chao Phraya basin have been affected. The swamps became shallow which would be the pool of water hyacinth. The study of the pool and pathways of water hyacinth in the irrigation system was conducted to determine and estimate the probability in controlling the infestation of water hyacinth.

143 FUNCTIONING OF TYPHA DOMINGENSIS (PERS) KUNTH STANDS IN CUBA

Jose Miguel Plasencia Fraga and Jan Kvet, Institute of Zoology and Systematic Science Academy of Cuba and Czechoslovak Academy of Sciences.

A study about the functioning of Typha dominqensis (Pers) Kunth stands was carried out in a reservoir at Sierra del Rosario, Cuba. The development of the stand, life cycle, above ground and underground biomass, net primary production, and accumulation and decomposition of autochthonous organic matter were determined. Above ground biomass was three times less than net primary production and almost five times less than accumulated dead material. Because of the low rate of decomposition, about 50% in a year, there was an accumulation of vegetal material which had an influence on the stand horizontal structure, decreasing shoot density and favouring the occurrence of species from outside the stand and therefore the destruction of the stand.

144 AQUATIC PLANT MANAGEMENT IN RELATION TO IRISH RECREATIONAL FISHERIES DEVELOPMENT

Joseph M. Caffrey, Central Fisheries Board, Balnagowan, Mobhi Boreen, Glasnevin, Dublin 9, Ireland.

Aquatic plant control programs are often conducted in isolation rather than as part of an integrated habitat management strategy. The impact that this policy has on recreational fisheries in Irish canals is described. The study aimed to examine the ecological impact of aquatic weed control procedures employed in the canals and to determine fish-holding capacity in relation to a range of aquatic plant species. Fish standing crop estimates were conducted using electrical fishing apparatus in canal habitats which had been subjected to different forms and intensities of weed control, as well as in untreated control sections. In excess of 2OO km of canal was examined during the investigation. Results revealed that reduced fish stock levels were recorded from canal sections which received severe mechanical cuts or where indiscriminate herbicidal control was applied. Moderately vegetated canals (20 to 70% cover) generally exhibited fish biomass levels which were between two and four times, respectively, greater than those recorded from densely (>70% cover) or sparsely (<20%) vegetated areas. Submerged plants with broad or complex leaf arrangements or mixed species assemblages had a far greater fish harbouring capacity than had either emergent or submerged, strap-leaved forms. The implications of these findings for future aquatic plant

management policy in Irish canal fisheries are discussed.

145 STATUS OF WATER HYACINTH AND CONTROL IN NIGERIA

Dr. O.A. Akinyemiju, Obafemi Awolowo University, Ile-Ife, Nigeria.

The only method of control adopted since the invasion of Nigeria coastal waters by water hyacinth (Eichhornia crassipes (Mart) Solms-Laub) in 1984 is mechanical control and this has so far failed to control or contain the spread of the weed and its attendant menace. To date, the weed has covered approximately 3,575 km 2 (50%) of Nigeria coastal brackish and fresh waters, and it is on the increase. In a series of studies to find alternate control measures, several herbicides were screened and a few tested in field pilot demonstrations for the control of water hyacinth. Terburtyn at 1 and 2 kg a.i./ha., diquat at 3 kg a.i./ha., paraquat at 1 and 2 kg a.i./ha., glyphosate at 3 kg a.i./ha., 2,4-D at 1 and 2 kg a.i./ha., ioxynil + 2,4-D at 3 kg a.i./ha., and imazapyr at 1 kg a.i./ha., affected a mortality of the weed within 2 weeks after application (WAA) and by 4 WAA, all the dead weeds had sunk. It is concluded that a judicious application of any of these herbicides will control water hyacinth and eliminate the menace caused by the presence of the weed in Nigeria.

146 AQUATIC PLANTS IN AGRICULTURAL CANALS IN YUGOSLAVIA

Marija Arsenovic and Branko Konstantinovic, Faculty of Agriculture, Institute for Plant Protection, Novi Sad, Yugoslavia.

The distribution of aquatic plants in irrigation and drainage canals in Yugoslavia has been investigated for over 20 years. Dominant submerged plants Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton spp. and Ranunculus spp. often cause flow-obstruction in the slow flowing drainage canals. The small free-floating plants Lemnaceae (Lemna trisulca, L. minor, Spirodella polyrrhiza) are more localized but can produce dense surface mats particularly in times of drought and reduced flow. Rooted floating-leaved plants (Nymphae alba, Nuphar lutea and Nymphoides peltata) compared with other groups of aquatic plants are lesser problems in agricultural canals. A special problem in canals can result from the following plant community: Typha latifolia, T. angustifolia, Phragmites communis, Carex spp., Glyceria maxima, and Juncus spp. In Yugoslavia aquatic plants have been controlled by mechanical, biological, and chemical means. In irrigation supply canals the submerged and rooted floating-leaved plants are controlled by mechanical means. Control of dominant emergent plants is obtained by the application of herbicides glyphosate, imazapyr, and glufosinate-ammonia.

ALTERNATE PAPERS

147 GROWTH AND SPREAD OF SCHINUS TEREBINTHIFOLIUS IN SOUTH FLORIDA

Francois B. Laroche and Daniel D. Thayer, Vegetation Management Division, South Florida Water Management District, West Palm Beach, Florida.

Schinus terebinthifolius (Raddi), native to Brazil, Argentina, and Paraguay, was initially introduced into the United States as an ornamental plant at the turn of the century. This evergreen, dioecious, insect-pollinated tree has been reported to have successfully naturalized in over 20 countries, in two subtropical belts (15 - 30° N and S) worldwide. In the United States it is found in Louisiana, Texas, California, Hawaii, Puerto-Rico, and Florida. It was not until after 1950 that Schinus became conspicuously dominant in south

Florida. It is a pioneer of disturbed sites such as highways, canals, levees, fallow fields, and drained bald cypress stands, but it is also successful in many undisturbed sites. Schinus has now successfully colonized many native plant communities in South Florida, including; pine flatwoods, tropical hammocks, and mangrove forest. The invasion of this aggressive, woody weed poses a serious threat to species diversity in many of south Florida's natural ecosystems, and is eliminating many indigenous sources of food for wildlife. In addition, it also poses several health problems to humans and wildlife. The growth habit and site requirements for the propagation of Schinus will be reviewed.

148 AQUATIC HERBICIDE APPLICATOR TRAINING IN THE SOUTHEASTERN UNITED STATES

Ken Langeland, UF, IFAS, Center for Aquatic Plants, 7922 NW 71st Street, Gainesville, FL

Science has provided us with diverse technology for management of aquatic plants. However, without trained aquatic plant managers to implement this technology, it is worthless. In today's environmentally aware, and often misinformed society, aquatic herbicide applicators are constantly under public scrutiny. To most effectively carry out their responsibilities, they must be skilled in pesticide application techniques, have a knowledge and understanding of basic aquatic ecology, and understand the applications and relationships between the different methods of aquatic plant management, which include herbicides, mechanical removal, biological controls, and physical techniques. Training and certification of applicators is a method of assisting applicators in obtaining knowledge and skills and of insuring that aquatic plant managers are of the highest quality. Therefore, development and implementation of training and testing materials for certification of aquatic herbicide applicators is a priority of the University of Florida, IFAS, Center for Aquatic Plants. Recently developed training materials include a hard copy and electronically available certification manual, slide tape set, and videotapes on specific training topics. Evaluation of the certification and testing programs has suggested that 98% of those questioned, who ranged from novices to experienced supervisors, considered the content appropriate and useful.

149 NUTRIENTS, AQUATIC MACROPHYTES AND FISH POPULATIONS IN STREAMS

Mark V. Hoyer and Daniel E. Canfield Jr., Department of Fisheries and Aquaculture, University of Florida, 7922 NW 71st Street, Gainesville, Florida, 32606.

A survey of 17 Florida streams was conducted to determine if the abundance of aquatic macrophytes was related to nutrient enrichment. Macrophyte standing crops were not correlated with in-stream total phosphorus or total nitrogen concentrations. Aquatic macrophytes contained less than 2% of the annual nutrient discharge in nearly all streams. Nutrients are, therefore, not considered to be the primary factor regulating the abundance of aquatic macrophytes in most Florida streams. Shading by riparian vegetation seems to be the dominant factor controlling the location and abundance of aquatic macrophytes. Total fish standing crop data in an extended data base from 79 North American streams located in Wyoming (n=20), Vermont (n=19), Florida (n=15), Iowa (n=12), Ontario (n=10), Washington (n=2), and Missouri (n=1) were used to test the hypothesis that stream fertility as indexed by total phosphorus concentration is an important environmental factor influencing fish standing crop. Total fish standing crop among the different geographical regions was not related to differences in latitude, but regional estimates of average fish standing crop were significantly correlated to total phosphorus concentrations. Total fish standing crop increased with total phosphorus concentrations throughout the range of reported values, but increased much more rapidly in streams having phosphorus concentrations $\leq$ 15 μg/l. This is consistent with the results of whole-stream fertilization experiments that have demonstrated that phosphorus enrichment enhances autotrophic production and fish abundance in nutrient-deficient streams.

150 SPECIFICITY OF MICROALGAL COLONIZATION ON EMERGENT MACROPHYTES, LAKE OKEECHOBEE, FLORIDA

Paul V. Zimba, Department of Fisheries and Aquaculture, University of Florida, 7922 N.W. 71 St. Gainesville, Florida 32606.

Epiphytic community structure on Typha sp. and Scirpus sp. was assessed. Samples were collected monthly from 2 adjacent sites located in Lake Okeechobee, Florida. Community structure was compared using SIMI to differentiate variance attributable to microalgal seasonality and differences in host species colonization.

151 AQUATIC PLANT MANAGEMENT IN TENNESSEE VALLEY AUTHORITY RESERVOIRS

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Significant declines in coverage of submersed aquatic macrophytes occurred in the Tennessee Valley Authority (TVA) main-stream reservoirs during 1989-1991. From a peak coverage of about 46,000 acres in 1988, following four years of record drought, the coverage declined to 13,600 acres by 1991 after three successive years of above normal rainfall in the critical spring months. Historical data is being examined to relate coverage of macrophytes with light, timing, and magnitude of flow regimes. Improved growing conditions for submersed macrophytes have been noted in 1992 following reduced spring rainfall.

A joint agency aquatic plant demonstration and applied research project on Guntersville Reservoir is now in the third year of a five year study. The TVA and U.S. Army Corps of Engineers have pooled their resources and expertise to examine varied projects, including aquatic plant management master planning, biological resources monitoring, large-scale grass carp demonstration, recreation/economic surveys, biocontrol agents, plant competition studies, herbicide residue investigations, Lyngbya biology, and convective circulation studies. Status of project tasks will be reviewed.

PRESENTER AND PAPER NUMBER