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Aquatic Weeds and Fisheries Production in Developing Regions of the World

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INTRODUCTION

It is a great honor to be invited by the Aquatic Plant Management Society to take part in your Annual Meeting and the International Symposium on the Biology and Management of Aquatic Plants. I would like to thank you for giving me the opportunity to come to your beautiful Florida and say a few words about aquatic plants and aquatic weed management which are a problem and challenge for developing countries in tropical and subtropical regions.

Perhaps you will excuse my bias toward fish and fisheries in my considerations of aquatic plants. As I note from the meeting agenda, not many fishery biologists attend your meetings. This is quite understandable, as the topic of the meeting is aquatic plant biology and management. Not being a botanist, perhaps you will also excuse me for occasionally getting lost in my fisheries thoughts as I consider myself more at home with aquatic animals than plants. I work for the Fisheries Department of the Food and Agricultural Organization (FAO) of the United Nations, and my bias will be toward applied aspects, and how to solve problems we face in our, if not daily, then perhaps weekly or monthly contacts with governments all over the world. I shall also concern myself briefly with the problem of aquatic plants in relation to waterborne diseases. For a number of years, through a joint World Health Organization - FAO Panel of Experts on Environmental Management for Vector Control (PEEM), much information has been collated, summarized, and disseminated to member countries on this and related topics.

If we have a complex problem involving water storage, water release, channelization, eutrophication, and health, we try to incorporate fisheries so that it fits in the multiple-use of land and water resources. We try to make the best use of natural conditions, including aquatic plants, to accomplish our major task of developing sustainable fish production in the great diversity of water bodies of the world.

Since biblical times, fish have provided and continue to provide a significant source of protein for the world's population. I shall attempt to describe how we attain this objective and I shall also identify the major areas on which we concentrate advisory, management and research activities.

WHAT ARE AND WHERE ARE THE AQUATIC PLANTS?

Where there are fish, there are usually also aquatic plants. Plants serve as shelter, food, and refugia from predators, and provide substrate for periphyton on which especially some of the young fish feed. Interrelationships between fish and plants are not simple, and are much more understood in temperate regions than in tropical and subtropical areas. Submersed plants are more appreciated in fisheries management than the emergent and floating species, and dense mats are less appreciated than loose aggregates of plants. Multispecies plant communities are better for fish than monospecific ones. In this respect, fish management and aquatic plant management share a common objective.

Then there is the diversity of water bodies. There are natural lakes and floodplain lakes, rivers and oxbows, reservoirs, irrigation canals and drains, lakes receiving drains from irrigation systems, and seepage lakes. We have smaller water bodies usually maintained by small rural earthen dams called tanks in India and Sri Lanka.

Aquatic plant managers can be employed by a hydropower-producing company such as the Tennessee Valley Authority or by WAPDA (Water and Power Authority in Pakistan) to monitor unwanted accumulations of aquatic plants, which we then call aquatic weeds, and which may cause difficulties in water intakes and in irrigation systems of their command areas. Irrigation companies and government irrigation departments will offer us the job of keeping their canals clear of weeds to prevent water losses and reduction of water flow. Health Departments will ask us to clear aquatic plants to prevent the spread of vectors of waterborne diseases such as malaria, arboviral diseases and schistosomiasis. Fisheries departments will request advice on how to make the best use of aquatic plants, but will also ask us to do something about excessive concentrations of aquatic weeds. Your job in the United States may be supported by sport fishermen's

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contributions, and you will then keep open for them fishing canals in Lake Okeechobee using large, and expensive, plant harvesters. Such behemoths may be found even in developing countries. The Government of India decided some years ago to import and use a harvester to improve boating for tourists in Srinagar, the capital of Kashmir, where Lake Dal, with its famous anchored boats, is infested with hydrilla (*Hydrilla verticillata*). Macrophytes can be used for secondary and tertiary sewage treatment, such as in Uganda, where the capital city of Kampala sewage treatment works discharge their effluents into the papyrus rim of Lake Victoria, or into special tertiary treatment ponds covered with water hyacinth like those studied a few years ago in Orlando, Florida. One can also be offered a job by a mining company which may ask us to remove heavy metals from tailings using floating aquatic plants.

As a fishery manager, I am interested in the use of plants in fish production or how to prevent a decline in fish production resulting from invasion by aquatic weeds. It is logical that I combine my fisheries interests with those of aquatic plant managers, engineers, and researchers to find the most appropriate means of solving each particular situation.

AQUATIC WEED PROBLEMS IN DEVELOPING COUNTRIES

The two major nuisance aquatic weeds in developing regions of Africa and Asia are salvinia (*Salvinia molesta*) and water hyacinth (*Eichhornia crassipes*). These species originated in Latin America where they do not cause major problems, at least not in the areas of their origin.

Salvinia molesta was described by Mitchell only in 1973 after it invaded Lake Kariba in Zimbabwe/Zambia. Zaire experienced a massive expansion of water hyacinth in the 1940s, and from there it spread to Sudan in the early 1950s. This was followed by a gradual spread of both plants through Africa, with the most recent invasions by water hyacinth being reported from West Africa. In East Africa the source of water hyacinth entering Lake Victoria is the Kagera River, whose origin is in Rwanda/Burundi. The Niger River in Niger is also "exporting" water hyacinth downstream to Nigeria.

In Asia, water hyacinth is a common occurrence on many village ponds in India and it grows rapidly, especially in heavily polluted ponds. Island states of the Indo-Pacific have not escaped aquatic weeds either, with Sri Lankan tanks being infested with salvinia, and with water hyacinth being a common plant in the Philippines. Papua New Guinea experienced a massive and explosive growth of salvinia on the Sepik River system in the late 1970s and the first half of the 1980s, which was brought under control by an introduced insect, and now water hyacinth is invading the same system. To control the salvinia problem on the Sepik River, Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) scientists collaborated with FAO in providing the insect *Cyrtobagous salviniae* and monitoring its spread to over some 200 km^2 of backwaters soon after its release. Within two years, there was a 99% reduction in salvinia, and concern was expressed that if the success were 100%, there would be no inoculum (insects) left to keep pressure on this weed species.

In the Philippines, water hyacinth is a major nuisance on Laguna de Bay, a lake near Manila, which has fish cage and pen culture. During the typhoon season, strong winds may blow masses of water hyacinth against these structures and cause their destruction. This act of God is, however, appreciated by capture fishermen, whose stocks are replenished by the escapees from cages and pens.

The reasons for the sudden occurrence of these two plants in various geographic areas are usually obscure, but it is frequently the result of ignorance. Salvinia, in its smallest phenotype, is an attractive floating aquarium plant and most aquarists do not know anything about the third phenotype, which causes large-scale infestations. Water hyacinth has beautiful flowers and can be found in flower shops in many countries. In Uganda the plant is still being sold as a decorative plant, although the government is publicizing it as a nuisance and raising public awareness to the problem and potential danger of the plant.

When salvinia appears upstream from its original point of infestation, it is evident that this is the result of a deliberate action. Indeed, in Papua New Guinea, local fishermen and villagers on infested lagoons decided to use the plant as a biological weapon to infest the upstream waters to make a point in their quarrel with neighbors.

On large areas, manual, mechanical, or chemical control methods cannot be applied. The cost of such measures is prohibitive and mechanical methods are slow compared to the regrowth rates. Biological control is usually less expensive, long term, and less harmful to the aquatic environment, but until recently its use on large-scale infestations was limited. The first major breakthrough in Asia was perhaps the control of the very large Sepik infestation of salvinia by *Cyrtobagous*. Since then, this control method has been applied in a number of other countries, including Sri Lanka, Botswana, Namibia, South Africa, and others. An equally efficient control of water hyacinth has not been found, although there exist several potential organisms, of which perhaps the beetles *Neochetina* spp. have the greatest potential, but are comparatively slow and less efficient than *Cyrtobagous*.

AQUATIC PLANT-FISH RELATIONSHIPS IN NATURAL SITUATIONS

A number of good reviews are available on this topic for the developed countries, such as that prepared by Canfield and Hoyer (1992) and by de Nie (1987). Reviews for developing countries are rare (*e.g.* Petr 1987).

To illustrate the situation for developing countries, I have selected several examples. The first one concerns floating meadows on floodplains of the Amazon river system. These rivers are of two types: those which carry so-called white waters, and are rich in dissolved nutrients as well as in aquatic plants, and those which are nutrient poor and are characterized by the dark color of water given to them by the presence of humic acids. The differences in their productivity are also reflected in the large differences in fish production.

The white waters of Solimões/Amazonas are rich in fish stocks and are an important source of protein to the region. The migratory characins (Family Characidae in the order Cypriniformes is a large family of economically important tropical food fishes) in these systems spawn at the beginning of floods and their fry/fingerlings grow and develop in the "varzea" floodplains, whose margins consist of dense vegetation, mainly *Paspalum repens* and *Echinochloa polystachia*. These and many other macrophytes of the "varzea" have floating root clusters which support rich invertebrate fauna, and these, together with detritus, provide an important food for the migratory characin fry and fingerlings. Other fish, such as *Colossoma*, feed mainly on filamentous algae and *Oryza* seed found in the floating meadows (Araujo-Lima, Portugal and Ferreira 1986).

In black and clear water regions of the Amazon basin, such as the Rio Negro, the aquatic floating meadows of grasses are less developed and diverse. Fishermen know of the significance of floating aquatic plants for holding or concentrating fish and use this knowledge to capture them.

Then there are the floodplain trees. In some countries tropical forest trees are resistant to long-term flooding. Such forests are present in the Amazon, but also in Cambodia, Indonesia, and the United States. During high water levels the flooded trees provide habitat and submersed surfaces for periphyton production. In Lake Tonle Sap in Cambodia, periodically flooded forests surrounding the lake contribute much to the fisheries production of the lake. Recent deforestation, followed by reclamation of the shallows for agriculture, has caused a sharp decline in fish catches. The Cambodian fisheries authorities have recognized this problem and have begun replacing trees on a small scale to return some of the lost production to the lake. Habitat restoration to increase fish production through planting water-tolerant trees, such as *Salix*, *Taxodium*, and *Eucalyptus* spp. were suggested for some U.S. reservoirs with water-level fluctuation. On the middle Kapuas in Indonesia, there are numerous black water lakes poor in nutrients, but with flood forests. In Lake Luar, the largest lake situated close to the Sarawak border, the presence of such forests is believed to sustain a high fish production.

Minimal clearing occurs in large tropical reservoirs constructed in savanna-woodland or in tropical forests because it is usually too costly and/or manpower is not available. The result is a direct benefit in the form of higher fish production, which persists for a considerable period of time, usually until the submersed trees eventually die and decay. The surfaces of the trees function as a source of food and shelter, and when aquatic plants become associated with them, they represent suitable spawning areas for many tropical fish species. In Volta Lake, Ghana, water lettuce (*Pistia stratiotes*) became widespread in areas of the lake with submersed or semi-submersed tropical forest trees. Elsewhere in the same reservoir a wide belt of the emergent grass *Vossia* developed along the water margins. Both plants had considerable significance for fisheries, but also served as vectors of waterborne diseases, such as larvae of mosquitoes and the snail *Bulinus*, the vector of schistosomes. It was determined that *Ceratophyllum* was largely responsible for the almost 100 percent incidence of schistosomiasis among children living along the shores of this reservoir. The dead trees also enhance the formation of sudd or floating islands in shallow waters. FAO evaluated the significance of flooded trees for fisheries and produced a publication by Ploskey (1985), which summarized the effects of flooded timber on fishery production in North America. Also, several studies are available on the significance of flooded trees for invertebrate and fish production in the Volta (Petr 1970) and Kariba (McLachlan 1970) reservoirs in Africa.

Managing lakes, reservoirs, and lagoons for increased fish production may be assisted by the provision of brushparks. Tree plantations may provide the material which, when submersed, will provide surfaces for periphyton and function as fish-attracting devices. The method, first described in Benin, West Africa, under the name acadja (Welcomme 1972) is now widespread. Sometimes aquatic plants are added. Annual fish yields vary from 2 t/ha, with fishing intervals of 3 to 4 days, to up to 17 t/ha with an interval of 70 days (Welcomme and Kapetsky 1981). But the requirement of wood for acadjas is about 10 t/year and this may be detrimental to the shoreline brushes and trees. The German Technical Cooperative Office in Benin identified seven tree species with a reasonable resistance to underwater decay and proposed to grow them on plantations.

USE OF AQUATIC WEEDS IN FISHERIES

The major importance of aquatic weeds for fish is to provide shelter, food and, to a lesser extent, to serve as a substrate for egg deposition. Relationships between aquatic plants and the centrarchids in North American lakes have been studied in great detail and they are now fairly well understood. This makes it possible to apply certain management measures if there is a demand for especially sport fish, or for the prey fish on which the sport fish feed. In Europe such relationships have been reviewed by de Nie (1987), and in some lakes fish have been manipulated for the benefit of fishermen. The use of such relationships in fisheries management in tropical and subtropical water bodies is less common, largely because they are unknown. The high demand for fish in Asia and Africa and the easy marketability of virtually all fish captured, even the small ones, have not made such research a priority. In Asia, the freshwater fish fauna west of the Wallace's line (a hypothetical line in the western Pacific Ocean separating the Oriental and Australian regions) is rich in species, and a single fish catch often consists of 30 or more species. Many species come from the same location as they feed on the same type of food. Cyprinids, the dominant group, are not very food selective, have high reproduction rates and grow fast. Studies of interrelationships of a large number of fish species are difficult. On the islands east of the Wallace's line, the poverty of fish species makes detailed studies easier and provides better opportunities for rational management.

Aquatic weeds or plants, depending upon one's definition, are used in some inland capture and culture fisheries in Asia. Lake Rawa Pening in Java, Indonesia, is large but very shallow. Since the introduction of water hyacinth into this lake, the plant coverage has varied over time. When the cover was excessive, the fishery declined. When water hyacinth receded, the fishery recovered and reached very high yields which is unusual for natural lakes. Water hyacinth has been accumulating in the form of peat at the bottom of the lake which is now "mined" for compost and gardening soils. In numerous places floating plants are herded behind bamboo stakes and left to attract fish which after a few days are captured by nets. Other methods of fishing are also applied including Chinese-type lift nets, gill nets, scoop nets, and dredges for prawns. Cage culture is also established, and around the cages water hyacinth accumulates, attracting even more fish.

Water hyacinth is in short supply on Lake Tempe in Central Sulawesi, but in great demand for structures called "bungka." To attract fish, water hyacinth and other floating plants are gathered behind sticks which are pushed into the lake or river bottom. Tree branches are often added as well. In Kalimantan, such systems are used on inland lakes of the Mahakam River in the east. On the Kapuas River in the west, water hyacinth is rarely found as it does not grow well in the black waters of these lakes. Any water hyacinth found is treasured and used as shade to protect fish in cages from direct sunshine, but no "bungka" are constructed there largely due to the lack of floating vegetation.

FISH IN THE MANAGEMENT OF AQUATIC PLANTS

In a 1989 report to FAO, Hartley (CSIRO, Brisbane, Australia) estimated the number of people to be negatively affected by floating aquatic weeds (water hyacinth, salvinia and water lettuce) in Africa. He estimated two million in Nigeria, including more than 24,000 fishermen. Approximately 100,000 persons living in riverine communities in Benin, West Africa, who rely solely on fishing for their livelihood, are affected. Additionally fishermen in Malawi and Ghana may be hampered by water lettuce. In the Niger, the recent explosive growth of water hyacinth has interfered with fishing on floodplains of the Niger River. In Lake Kyoga in Uganda, thousands of fishermen may not have access to landing sites and to fishing areas blocked by water hyacinth.

Biological control of aquatic weeds is the only hope for weed management in large water expanses. Recall, however, that the natural spread of biocontrol agents can have a detrimental effect on fish production in areas that rely upon aquatic weeds to increase production and on fishermen who use aquatic weeds as fish attractants. On a smaller scale, fish can be used to control some plants, especially submersed species. Grass carp is presently the most suitable species, but tilapia (*T. rendalli*) and tawes (*Puntius gonionotus*) have also been successful in some environments. They are food selective, preferring submersed weeds, and to achieve fast results the weeded areas may have to be overstocked. Overstocking also is required to overcome the exceptional abilities of fishermen to utilize nets to non-selectively harvest fish that are stocked to control aquatic weeds.

An advantage of using fish for aquatic plant control is that plant destruction is gradual and thus relatively safe for the environment as there is less danger of rapid deoxygenation of water such as that resulting from chemical control which kills plants suddenly. The side effect of biocontrol with fish is sometimes the eutrophication of water which may lead to algal blooms. This can be used to advantage by stocking plankton-feeding fish or a polyculture-type approach. Grass carp has been successfully used in irrigation systems in Egypt (van Zon et al. 1982) and in Turkmenistan (Charyev 1984).

The Kara Kum in Turkmenistan is an artificial canal 1,000 km long, which branches off the Amu-Darya River. The flow at the canal headworks is 400 m^3/sec. The muddy waters of the Amu-Darya then enter the Kelif lakes where the suspended sediment gradually settles. In the last of these lakes, the Secchi disc transparency is 2.3 m, which encourages growth of macrophytes. Only parts of lakes and canals deeper than 5 m are free of aquatic weeds, and even the smallest distributaries are invaded.

To sort out the problem of aquatic plants in the system, grass carp was introduced in 1958 and released in large numbers in 1960 and 1961. By the mid-1960s, large-scale natural reproduction of grass carp took place and within a few years most of the aquatic macrophytes disappeared. Some problems, however, remain. Selective feeding of the grass carp has led to succession in macrophytes, with *Myriophyllum spicatum* being replaced by *Ranunculus*, which is considered toxic to grass carp. Charyev (1984) summarized the experience with the introduction of grass, silver, and bighead carps into the Kara Kum canal and emphasized the need to protect the higher aquatic vegetation, particularly in cases where macrophytes represent spawning substrate for other fish, such as common carp. In excessive numbers the grass carp can cause great damage to a body of water as an ecosystem, destroying existing food-chain relationships and threatening the spawning grounds of commercial fishes.

Grass carp, through its intensive grazing activity, also contributes to the eutrophication of water bodies. The deterioration of water quality, which is undesirable in deserts where alternative potable water supplies are rare, was successfully countered by silver and bighead carps which live on phytoplankton, zooplankton and detritus. These two species prevented phytoplankton blooms and deterioration of water quality. In the system of canals and reservoirs of the Kara Kum canal, the three carp species constitute 75 to 80 percent of the total catch and yield 45 kg/ha/year (Charyev 1984).

Environmental impact of grass carp on the aquatic ecosystem cannot be disputed: by suppressing some species of macrophytes other species may increase; by grazing off some plants the spawning substrata of important fish may disappear; without a counterbalance of phytoplankton-feeding fish, water quality deteriorates. Aquatic systems function best with a moderate abundance of aquatic macrophytes and introduction of grass carp could assist in reaching such equilibrium. But as Charyev (1984) stated, without grass carp, the irrigation system of canals and reservoirs in the Karakum desert would be much worse than with it.

BIOMANIPULATION

In 1989 I attended an international conference on biomanipulation of water quality in Amsterdam. Ozimek *et al.* (1990) described an example where the stocking of planktivorous fish resulted in the restoration of submersed aquatic plants due to improved transparency of water for light. Biomanipulation for restoration of aquatic ecosystems has focused mainly on inland lakes in temperate latitudes. Modeling such situations requires considerable data of good quality, something we still lack for most similar situations in developing countries. Standard models of relationships for temperate waters are not necessarily applicable for warm waters, where reactions are faster and the number of relationships greater. Fish have been used for biomanipulation on a large scale in Lake Kinneret in Israel, largely for the purpose of maintaining good water quality (Leventer 1981). This biomanipulation targeted especially heavy blooms of *Peridinium*. However, finding the right management strategy has been difficult. For some 20 years stocks of fish have been manipulated including the introduction of exotics, and trying various stocking rates. The results show the difficulty of using the biomanipulation approach in a large water body, but the Israeli experience has also provided a wealth of data which would not be obtained otherwise. Much flexibility on the part of managers and on-going research are two basic conditions for using this approach in warm-water bodies, particularly those used as a potable water supply.

AQUATIC PLANTS, VECTORS OF WATERBORNE DISEASES AND FISH

Allow me to deviate to rice, the most common aquatic or semi-aquatic plant in the world. Ricefields are considered wetlands or semi-wetlands and are frequently associated with other aquatic plants. There are over 150 million hectares of ricefields worldwide, of which about 80 million hectares are irrigated rice areas, representing some 35 percent of the total area of irrigated crops. Ricefields harbour a number of vectors of parasites or viruses causing diseases such as Japanese encephalitis (*Culex* mosquito), malaria (*Anopheles* mosquito), yellow fever (*Mansonia* mosquito), filariasis (*Culex* mosquito), and schistosomiasis (snails *Bulinus*, *Biomphalaria*). *Anopheles gambiae*, the main vector of malaria in Africa, is often found in high densities in ricefields. The same vectors are found in many aquatic plants including water lettuce and water hyacinth. *Bulinus* is common in *Ceratophyllum*, and blackflies, the vectors of a parasite causing river blindness, are common on submersed plants in rivers, streams and canals.

In large ricefields, mechanization may lead to mosquito outbreaks which are much less common in more traditional agroecosystems. Such systems usually combine rice production with production of vegetables, edible molluscs and fish, and fodder for cattle. Ideally, although many vectors can exist, the complexity of animal populations and predator pressure (including fish) limits productivity of any one vector (Bradley 1988). In Nepal and Afghanistan, biological control of mosquitos using larvivorous fish has been successful and a similar success was achieved in ricefields in Java. Control of snails harboring schistosomes is also possible, especially in a pond situation, using haplochromine fish. In strict rice monoculture, such as that practiced in California, larvivorous fish may fail to control the vectors (Blaustein 1972). Observations showed that introducing larvivores triggered reactions which no modeling could predict.

Large-scale irrigation projects in Turkey, some already completed, urgently need advice on how to deal with the combined problems of aquatic weeds and disease vector control. The use of fish has been proposed as one of the alternatives.

AQUATIC PLANTS AS FISH FOOD

Grass carp is not only an aquatic plant control agent but also an important fish of semi-intensive and intensive pond culture where it is daily fed terrestrial grasses and vegetable waste.

A more sophisticated system has been developed in China and Vietnam where the duckweeds (*Lemna*, *Wolffia* and *Spirodela*) are grown to supply feed for pond and ricefield-raised fish. In Taiwan a system using *Wolffia* and *Lemna* for feeding young fish is well developed for Nile tilapia and common and grass carp. In China, grass and common carp in ricefields are grown to fingerling size, providing a yield of 225 to 300 kg/ha or even higher, depending on which system (single or double cropping) is applied. Such fingerlings are then used for stocking ponds where they are grown to marketable size. Duckweeds can be grown on septage, then fed to tilapia. In Thailand, Edwards, Polprasert and Wee (1987) reported yields of *Spirodela* in septage-fed ponds of approximately 9 t dry weight/ha/year in long-term experiments. In family ponds, 7.4 t/ha/yr was possible. While *Spirodela* can be used only as supplementary feed for large Nile tilapia, grass carp, and silver barb (*Puntius gonionotus*), *Lemna* and *Wolffia* were readily eaten. These plants can assist in solving the often difficult task of disposing, but also utilizing, domestic sewage in tropical countries and have the side benefit of producing feed for fish.

The fern *Azolla* is another useful plant. The tilapia *Oreochromis niloticus* derives 50 to 80 percent of its body weight from *Azolla* in the rice-*Azolla*-fish system, and the rate of *Azolla* digestion is 59.7 percent (Liu Chung-Chu 1987). In their feces, these fish excrete 40 percent of the nitrogen, which means that they assimilate 60 percent of *Azolla* nitrogen.

In the fish-rice-*Azolla* system *Azolla* also controls aquatic weeds. In India *Azolla* reduced growth of the emergent grass *Echinochloa* in rice paddies and increased the grain yield. Under suitable conditions *Azolla* can supply the entire nitrogen requirements for a high yielding rice crop in 10 to 20 days. *Azolla* is used for feeding not only fish, but also livestock and poultry, especially ducks. *A. filiculoides* tolerates up to 0.7 percent salt water and can be used for reclamation of coastal saline soils. If cultivated for two years, the salt content may decrease from 0.35 to 0.1 percent (Shang *et al.* 1987). This could perhaps be used in swamp and coastal pond fisheries, where acid sulfate soils are a major obstacle to achieving good prawn and fish production. The disadvantage of growing *Azolla* is the demand for labor which is not readily available in some countries. Also, intensive rice culture on large fields does not allow the use of *Azolla*.

EQUILIBRIUM, SUSTAINABILITY, MANAGEMENT, NEEDS

Having provided a number of examples of problems caused by aquatic plants, and of their benefits, especially for inland fisheries in developing countries, I shall try to identify some future needs. Before answers can be given, it is necessary to ask a few questions.

One of the spinoffs of the rising environmental consciousness is the wish to maintain natural equilibriums. There is a feeling that exploitation of resources should be replaced by sustainability, *i.e.* by managing natural resources (or exploiting them) on a sustainable basis. Can this be done? It cannot be done with minerals, but it can be done with biological resources. With an ever-increasing human population and demand for improved living standards, sustainable growth seems to be the only solution. How do aquatic plants fit in? In the developed as well as less developed world we wish to preserve species diversity, healthy growth, and nice flowers. But we also need aquatic plants for management and we have been looking at how to use them as management tools in the removal of pollutants, as fodder for cattle, as a medium for fish spawning, provision of shelter, and substrates for grazing. In some countries they provide cellulose for manufacture of paper. To sustain these functions of aquatic plants requires management. Sensible management means that we must understand the principles determining equilibriums and that we can identify the upper and lower limits of management. This is still a difficult task, requiring research, something which may be available in developed countries, but not usually present in the rest of the world.

Aquatic plant management research needs to be both basic and applied. The cost of basic research is high, and in most developing countries such research is still a luxury, although an increasing number of laboratories there now receive financial support, laboratory equipment and professional advice with training on the job or outside the developing country. There exist centers of excellence such as the

Asian Institute of Technology in Bangkok and the International Rice Research Institute in Los Banos in the Philippines. Some international organizations also coordinate local or regional research, such as the Wetlands Bureau in Bogor, Indonesia. Time is now ripe for networking among such organizations, which still largely work in isolation.

Transfer of knowledge from developed (often temperate) to developing countries (often tropical) is possible, but such knowledge is not always applicable. A good example is the tremendous amount of basic and applied research conducted on centrarchid and salmonid fisheries in the temperate zones, very little of which is useful to developing countries. Therefore, there is a need for research and training. To find a correct approach, training on a technical level may be more important than training resulting in a higher university degree. Developing countries may have western university graduates of excellence, but few with home country experience. Often these graduates may not wish to descend, in their opinion, to research or applied science on problems similar to those solved in other countries half a century ago.

Dissemination of results from research and applied science of local scientists also presents a problem. They lack peer reviews of their work as there are few scientists who work in the same field in the same country. Their contact with laboratories and researchers outside are limited. The English language is now the widely accepted medium for scientific communications and this still represents a problem for sizable groups of good scientists in non-English speaking countries, making the results of their work poorly known in the outside world. There is also a financial barrier between the developed and developing world, which prevents purchase of new publications and subscriptions to scientific journals. While computerized information retrieval systems may be accessible, the information obtained from them is good for reviewers, but not always of much use to scientists in the field.

International organizations have assisted with the production of manuals and guidelines and with their translations into local languages. Such manuals, often produced in collaboration with local scientists or entirely by them, not only address the problems, but also advise on their solution. Videotapes addressing specific problems are also becoming available and reach many developing countries.

COORDINATION, FEEDBACK

As noxious aquatic weeds such as salvinia and water hyacinth often transcend borders, their control may require trans-national coordination. Water hyacinth arriving in Lake Victoria from Rwanda through the Kagera River, or the same plant reaching Nigeria through the Niger, are two examples. Solving the problem requires international collaboration and coordination of activities as proposed by CSIRO, the International Institute for Biological Control (IIBC) and a few other organizations. Monitoring of the global spread of water hyacinth in many Anglophone countries was undertaken in the early 1970s by the Commonwealth Secretariat, but there is a need to review the situation again.

An integral part of the coordination for control of aquatic weeds is education of people through mass media about the hazards of aquatic weeds. When the Sepik River people in Papua New Guinea started transporting salvinia in their canoes to surreptitiously introduce this plant to lagoons of neighboring villages, they had little idea that they were speeding up the process of a complete blockade and isolation of their own villages.

Coordination also implies that aquatic plant managers look beyond their own problem, placing it in a broader context of the environment and watershed development. They need to know about watershed manipulation, water storage and diversion, irrigation, rice production, cotton production, pesticide application, etc. Shallowing of lakes by siltation from deforestation and excessive inputs of sewage will impact aquatic plants. A good manager will attempt to solve complex problems in close collaboration with other interested parties and to their mutual benefit.

Finally there is the need for monitoring and feedback. Many activities in the field terminate after a certain period of time, deemed sufficient for their implementation. In the case of aquatic plant management we know that it is not possible to leave such a dynamic biological system without monitoring, especially in a situation with potential for renewed explosive growth. Monitoring the introduced control agents is especially needed in remote parts of some countries which could become focal points for future invasions. Regular monitoring of the post-project situation should be included in management plans. Few governments realize that the cost of the monitoring may be less than launching similar projects again in the future.

CONCLUSIONS

What is the solution to an aquatic plant management problem? The answer will be in a good description of the problem.

Describing a problem may not always be easy. A problem for one interested party may not be a problem for others. In multipurpose use of water and land resources, aquatic plants or weeds are only one item in a complex system. A hydropower dam engineer may not necessarily insist on good water quality, but will require destruction or removal of floating aquatic weeds. A water supply manager will tolerate aquatic plants which do not decay on a large scale, and will accept a reasonable growth of submersed plants. The manager may collaborate with a fisheries manager, who will advise on how to use fish to maintain good water quality. Sport fishermen, rare in developing countries, will request good sport fish to catch, usually a predator. But the introduction of a predator to some water bodies may be controversial and detrimental. We have heard a lot of criticism about the introduction of the Nile perch into Lake Victoria, which substantially changed the lake aquatic environment, but on the other hand has led to a flourishing fishery. Fish production managers may accept eutrophication and may therefore not be interested in water quality improvement. In summary, advice will not always satisfy everybody and may even involve some risk.

In developing countries we have to weigh the economic, social, and environmental costs of an action. Some of you may disagree with the order in which I list the above costs, but it is indeed still largely the economics which determines whether to cut littoral weeds, to buy a weed harvester, or to invest in chemicals to spray. Technical advisory agencies provide advice, but the enforcement of a particular approach is in the hands of the government. If the government has not enough money to introduce the best control method (or to allocate several specialists to deal with the task, or to establish a research laboratory), our advice may not be implemented.

For some time to come, developed countries will remain the vanguard of in-depth, sound, and applicable research and of devising the best ways for aquatic plant and weed control and management and assisting with the transfer of experience and technologies to developing countries.

In conclusion, I have prepared a short list of aquatic plant management priorities compiled in response to requests for assistance addressed to FAO. The list reflects two basic demands of people in developing countries: food and health.

1) Control of exotic aquatic macrophytes with mass distribution in open waters such as in the Niger River, Lake Kyoga and Lake Victoria, reservoirs in Cuba and Bolivia, and the Sepik river system. The major reason given for such requests is the damage aquatic weeds cause to fisheries.
2) Control of weeds and aquatic plants in numerous irrigation canals and drains. The major reasons given for requests include water loss, slowed distribution, control and eradication of parasitic and arboviral disease vectors.
3) Rehabilitation of aquatic plants in lakes under the impact of eutrophication. The major reason for this request is to re-establish the original fish, crab, and prawn fauna such as in lowland lakes of the Yang-tse river in China.
4) Assessment of the significance of wetlands for fishery. Apart from providing an inventory and program for fishery management, such surveys are to assist in the protection of wetlands against encroaching agriculture (*e.g.* in Nigeria).

This symposium has provided me the opportunity to as that you consider the vast importance of your work to man millions of people in developing nations and further conside your activities with the respect to the four priority areas I hav described above.

LITERATURE CITED

Araujo-Lima, C. A. R. M., L. P. S. Portugal and E. G. Ferreira. 198€ Fish-macrophyte relationship in the Anavilhanas Archipelago, a black water system in the Central Amazon. J.Fish Biol. 29:1-11.

Blaustein, L. 1972. Larvivorous fishes fail to control mosquitoes i: experimental rice plots. Hydrologia 232:219-32.

Bradley, D.J. 1988. The epidemiology of ricefield-associated diseases. *In* Vector-borne disease control in humans through rice-agroecosysten management. Internat. Rice Res. Inst. Philippines. pp. 29-39.

Canfield, D.E., Jr., and M.V. Hoyer. 1992. Aquatic macrophytes and thei relation to the limnology of Florida lakes. Final Report. Center fo: Aquatic Plants, Institute of Food and Agricultural Sciences, Universit of Florida, Gainesville, USA. 599 pp.

Charyev, R. 1984. Some consequences of the introduction and acclimatization of grass carp, *Ctenopharyngodon idella* (Cyprinidae), in the Kara Kum Canal. J. Ichthyol. 24(3):1-8

De Nie, H. W. 1987. The decrease in aquatic vegetation in Europe and its consequences for fish populations, EIFAC/CECPI, FAO, Rome. Occas. Pap. No. 19. 52 pp.

Edwards, P., Ch. Polprasert and Kok Leong Wee. 1987. Resource recovery and health aspects of sanitation. Asian Institute of Technology, Bangkok, Thailand. Res.Report No. 205. 324 pp.

Leventer, H. 1981. Biological control of reservoirs by fish. Bamidgeh 33(1):3-23.

Liu Chung-chu. 1987. Reevaluation of Azolla utilization in agricultural production. *In*: Azolla utilization. Internat. Rice Res. Inst. Manila, Philippines. pp. 67-76.

McLachlan, A. J. 1970. Submerged trees as a substrate for benthic fauna in the recently created Lake Kariba (Central Africa). J. Appl. Ecol. 7:253-66.

Ozimek, T., R. D. Gulati, and Ellen van Donk. 1990. Can macrophytes be useful in biomanipulation of lakes? The Lake Zwemlus example. Hydrobiologia 200-201: 399-407.

Petr, T. 1970. Macroinvertebrates of flooded trees in the man-made Volta Lake (Ghana) with special reference to the burrowing mayfly *Povilla adusta* Navas. Hydrobiologia 36:373-98.

Petr, T. 1987. Fish, fisheries, aquatic macrophytes and water quality in inland waters. Water Quality Bull. 12(3):103-6 and 128-9.

Ploskey, G.R. 1985. Impacts of preimpoundment clearing on reservoir ecology and fisheries in the United States and Canada. Rome, FAO Fish. Tech. Pap. No. 258, FIRI/T258, 35 pp.

Shang Deng-hui, Wu Ho, Chen Xi-pan, Gu-Rong-sain. 1987. The cultivation of *Azolla filiculoides* for the reclamation and utilization of heavy saline soil. *In*: Azolla utilization. Internat. Rice Res. Inst. Manila, Philippines. p. 274.

Van Zon, J. C. J., J. E. Blom and E. A. Huisman. 1982. Irrigation systems as protein source. *In*: Int. Symp. Herbivorous Fish. pp. 133-8.

Welcomme, R.L. 1972. An evaluation of the acadja method of fishing as practised in the coastal lagoons of Dahomey (West Africa). J. Fish Biol. 4:39-55.

Welcomme, R.L., and J.McD. Kapetsky. 1981. Acadjas: the brush park fisheries of Benin, West Africa. ICLARM Newsletter, Vol. 4, No. 4:3-4.

J. Aquat. Plant Manag. 31: 13-17

PLENARY ADDRESS

Ecological Crisis in Post-Communist Central Europe

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INTRODUCTION

The countries of Central Europe which liberated themselves from Communist rule in 1989 (Czechoslovakia, Hungary, Poland and former East Germany) have inherited a weak economy and a severely deteriorated environment. The poor state of these countries is the result of the wasteful Marxists' attitude toward natural resources and of their small respect for environmental protection and nature conservation. The "new democracies" of Central and Eastern Europe are now facing a serious ecological crisis which is coupled with their economic difficulties. I will confine my presentation of this situation to the aforementioned four post-Communist countries situated at the heart of Europe while most examples will be drawn from my home country, now divided into the Czech and the Slovak Republics.

SYMPTOMS OF THE ENVIRONMENTAL CRISIS AND ITS CAUSES

In all four countries, the ecological crisis shows similar symptoms. Among the most conspicuous ones are drastic changes in the hydrological balance of whole regions, especially increased instant discharges caused by large-scale drainage of agricultural land, high levels of air and water pollution, heavy eutrophication of many standing and running waters and soils, and the acidification of others. Further symptoms, often associated with the previous ones, are a deterioration of soil quality (soil degradation), especially reduced soil humus content and waterholding capacity, and damage to forests leading even to forest dieback. The severe damage to some forest-tree species [especially conifers such as Norway Spruce (*Picea excelsa*) and Silver Fir (*Abies alba*) is parallelled by an equally severe damage to some species of aquatic and wetland plants such as some water lilies (*e.g.*, *Nymphaea candida*, *Nuphar pumila*), bulrushes (*e.g.*, *Scirpus lacustris*) and reeds (*Phragmites australis*). The generally raised nutrient concentrations in rainwater, soils, and surface and ground water bring about an impoverished species composition of biotic communities, due to the enhancement of just a few species populations that can make use of increased nutrient inputs and outcompete other species populations. Acidification has a similar effect: it is only the acid-tolerant species that can relatively thrive in areas which are strongly affected by acid rain and snow fall. These are areas with shallow podzolic or semi-podzolic soils on acidic geological substrates, mostly in the highlands or mountains. A decline in biodiversity and dying out of some species of green plants and associated fungi and animals are thus the result of both eutrophication and acidification of soils and waters. On top of that come the direct effects of environmental pollution, with all three main biosphere compartments (atmosphere, hydrosphere and pedosphere) acting as its vectors.

Human health is also adversely affected by the unfavorable environment. In most post-Communist countries, the average life expectancy is shorter by several years than in other comparable countries of Europe. The direct effects on human health are largely due to air pollution; the indirect effects are still rather obscure, but high concentrations of nitrate in many sources of drinking water and residues of agricultural chemicals and maybe PCB's are among the likely reasons, though bad food habits of the majority of Central European people can also be blamed (Figure 1). The environmental awareness of the general public is still relatively low although it is growing slowly. However, at present most people seem to be most interested in improving their economic situation, and environmental considerations play a secondary role in their decisions (perhaps with the exception of the people living in regions with the most severely deteriorated environment). Systematic environmental education, especially of the young people and children, is essential for improving the situation. A consumers' society should not be our goal!

In short, it may be stated that under Communism we lived at the expense of our children and grandchildren. In the new

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