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ECONOMIC DAMAGE CAUSED BY AQUATIC WEEDS

(Preliminary Survey)

Office of Science and Technology
Agency for International Development
Washington, D.C.

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Preface

In recent years there has been a growing concern among developing countries and development agencies about the steady proliferation of various species of aquatic weeds in tropical and subtropical regions. A few surveys have been made by teams of scientific experts, symposia have been convened, and a variety of literature exists on the kinds, distribution, and ecology of aquatic weeds, both anchored and floating, in developing countries. Increasing attention is now being given to techniques for controlling the growth of such weeds. Mechanical, chemical, genetic, and biological control techniques have all been proposed, examined, and in some cases tried. Biological control techniques, especially, are now being suggested as most promising and rewarding in terms of costs to developing countries and minimal disturbance to the environment.

While it is widely recognized that aquatic weeds can cause considerable damage, thereby retarding economic growth, there has been no serious attempt to quantify, estimate, or even define the extent of the weed nuisance in developing countries in terms of specific economic losses. Therefore, a sound basis is lacking for determining the priority among competing demands on limited resources that should be given to aquatic weed control schemes.

This Report attempts to estimate in a very preliminary way the economic significance of the aquatic weed problem in developing countries. It is clearly not possible to define economic losses in exact dollar terms. Precise information does not exist nor could it be developed concerning the damage caused by specific weeds in specific settings, let alone the overall impact, including secondary effects, on an economy. Instead, an attempt is made to develop order-of-magnitude estimates for selected types of damage caused by weeds in specific settings. Such broad estimates should at least place the problem in better perspective and provide some guidance as to the priority that should be attached to corrective action in this field.

The Report is limited to the problems of weed infestation in rivers, streams, canals, reservoirs, ponds, lakes, harbors, and similar bodies of water. The economic losses in agriculture due to weeds in fields are addressed in other reports supported by the Agency, and therefore examples of such losses in rice paddies, irrigation ditches, and other agricultural settings are not included.

I. TYPES AND DISTRIBUTION OF AQUATIC WEEDS

An "aquatic weed" is defined in this report as any plant which has an inimical effect upon the physical and biological aquatic environment, with resultant economically damaging consequences. Aquatic weeds can be classified in three broad varieties: submersed, emergent, and free-floating. There are dozens of widely distributed species which can be included in the definition of weeds but which are, at worst, nuisances of no great economic import, with natural influences imposing reasonable checks and balances upon their growth and spread.

However, several species which are apparently relatively immune to natural ecological restraints have reached a state of serious concern. They are economically significant in some parts of the United States and in many developing countries. A representative list of some of the most harmful species and an indication of their distribution follow:

Common Name	Plant Type	Location
Waterhyacinth (*Eichornia crassipes*)	Floating	All subtropical and tropical regions with fresh water bodies have some infestation. Critical regions include Mekong area, Ceylon, Malaysia, Congo River region, Upper Nile, Botswana, Niger, Borneo, Sumatra, Java, Guinea, Brazil, Venezuela, India.
Waterfern (*Azolla* spp.	Floating	Mekong area, Lake Kariba, Ceylon, Congo River region, Upper Blue and White Nile.

Common Name	Plant Type	Location
Waterlettuce (*Pistia stratiotes*)	Floating	Mekong area, Upper Nile, Dahomey, Guinea, Ivory Coast, Mali, Mauretania, Gambia, East Africa, Senegal, Nigeria, Cameroons, Congo River region, parts of India, Malaysia, scattered parts of Central America.
Hydrilla	Submersed	Mekong area, Northeast Thailand, Laos, India, Madagascar, Southeastern U.S.
Alligatorweed (*Alternanthera philoxeroides*)	Emergent (Marginal and floating)	Northeast Thailand, Indonesia, West Bengal, Laos, Vietnam, Southern U.S.
Sedges (Cypsracsas)	Emergent (Marginal)	Upper Blue and White Nile, Mekong area, Lake Victoria, Malaysia (Cosmopolitan).

While all developing countries with a suitable climate and water resources are affected in some measure by weeds, some are more burdened than others. The economies of many developing countries are presently, or soon will be, noticeably affected by the spreading of weeds. An example is Ghana. With its important Volta Lake and contributory riverine system, it may be on the verge of a runaway infestation. Already many weed species are present and rivers are beginning to be clogged, although the lake itself is not yet critically affected. However, the situation on the lake may well be hyperstable.

The free-floating species are the most prevalent throughout the developing world and here they exert the greatest present and potential economic impact. Waterhyacinth is the most damaging. With few natural checks,

it forms dense mats or sudd with weights up to 200 tons per acre of water surface. It has the most rapid growth rate and widest geographical distribution, including many inland water areas in the United States as well as in the tropics. Long recognized as a serious and costly nuisance in Florida and Louisiana, the waterhyacinth is being increasingly viewed as both an economic and health hazard in many developing countries, which often depend on aquatic products, river transportation, and water power, and can ill afford such barriers to development. 1/

1/ The waterhyacinth spreads by regeneration from viable fragments, such as stolons, and by dissemination of seeds. High temperatures and/or intense sunlight are necessary for seed germination. Germination is usually most effective in shallow warm water, although, where rapid nighttime atmospheric cooling is a factor, the seeds seem to germinate better in deeper water with a more constant temperature. The seeds can withstand dry-bank exposures and wide temperature variations and still show about 50 percent germination. The seeds are adaptable and seem remarkably versatile in their choice of habitats. They can settle on river banks, floating debris, logs, and even boat hulls. They will germinate most readily among shore-line debris, rotten vegetation, and humus. The plant spreads not only by stolons or seed but also by physical movement. The growing season extends throughout the year in most of its habitat, and in a suitable environment, the plants double in number every two weeks.

II. TYPES OF DAMAGE CAUSED BY AQUATIC WEEDS

Water evaporation losses are greatly accelerated by the large surface area presented by the leaves and other plant members. The leaf structure of floating and emergent plants presents a surface area exposed to the atmosphere, and water rising through the plant is "transpired" (i.e., evaporated) through the leaf's pores. Thus, at an ambient temperature of 76 degrees and relative humidity of 50 percent, reservoir water losses are known to reach 20 percent in the presence of heavy weeds as contrasted to a normal five percent loss from an open-water surface, since transpiration is a far more efficient fluid transfer mechanism than normal evaporation. It has been reported that as much as half of the potentially useful water of the Upper White Nile is lost through increased water loss resulting from the weeds. These transpiration losses can result in a very significant loss of hydraulic head for power systems and water for irrigation and settling ponds.

The water/air gas exchange is unbalanced by sizeable floating mats of aquatic weeds, particularly in those instances when they cover over 20 percent of a water area. The oxygen content of the water is reduced so that fish suffocate. The ecological food chain for aquatic life is interrupted through retardation of plankton growth resulting from lack of sunlight. Moreover, decomposing vegetation consumes oxygen and may contribute to fish kills.

Breeding of mosquitoes and bilharzia snails is often accelerated in weed masses. Clearly, normal control methods for these pests are seriously hindered by the weeds. Also, there is suspicion, but little specific data, that the weeds provide favorable environments for the rapid spread of other disease bearing organisms.

The clogging of sewage lines and other interference with sewage disposal and drainage systems can be damaging. The sewage provides abundant nutrients and, in open ditches, holding tanks, and lines, with warm temperatures and sunlight, the floating weeds may proliferate at a great rate. Besides the obvious health hazards which result, considerable inconvenience and expense is involved in repairing and cleaning the sewage systems.

Water current flow velocity can be reduced significantly by weed colonies. Also, floating mats may expedite the rate of silt deposition, and increase the likelihood of flooding. Just to keep a waterway channel such as the Nile and its tributaries in the Sudan reasonably navigable requires major cutting and dredging operations. A large dredge with a ten-ton scoop, even in a region with inexpensive labor, can cost $200 per day to operate -- and dozens may be needed in a hundred-mile stretch of water.

Flood and general water control may be seriously hampered by the choking of drains and diversionary canals and the clogging of flood control gates. The water, instead of being properly diverted into run-off basins or ponds, backs up and increases the very flood danger that the canal system was designed to avert. Such problems have been encountered in the Grand Loc region of Cambodia, the Sudan, the Blue Nile region of Ethiopia, and scattered localities in the Orinoco basin.

Weed interference with hydroelectric power plants is an actual and potential hazard, especially when penstocks and intakes are near the water's surface. The floating mats may clog the intakes. While good dam design can obviate this hazard to a large extent, there is often an added expense, and the danger is appreciated by engineers associated with various hydropower projects in South America, Africa and India. The Lake Volta project, for example, although relatively new shows signs of weed interference with water flow into penstocks. As the weeds die they tend to settle to the lake bottom and then congregate at the outlet areas. While the high hydraulic head may prevent serious clogging in this case, in projects with a lesser head, weeds could prejudice efficiency, despite the best engineering design.

Water transport and fishing are seriously restricted by aquatic weeds, resulting in substantial economic loss to developing countries as explained in Section III. The weeds not only contribute to the physical obstruction of navigation, but where infestation is not so severe as to limit fish populations, the weeds may obstruct the use of nets and boats.

III. ECONOMIC IMPACT - GENERAL CONSIDERATIONS

The damage and problems caused by weeds can have, in varying degrees, a negative effect upon a country's economy. Whereas a developed country, such as the United States, can readily absorb such economic losses, as have occurred in Florida, Louisiana, Mississippi, and Georgia, such losses cannot be easily accepted in a developing country. Countries which have few waterways or other fresh water bodies can be more seriously affected than "wetter" countries with much fresh water and an extensive riverine network. In countries straddling or bordering the Niger, the Congo, or the Nile rivers, for example, weeds can be a very serious potential threat to the overall economy. Even in the "wetter" countries such as Ceylon, India, Guyana, and Brazil with many ancillary waterways, massive weed infestation will, with time, have measurable economic consequences, especially where the major rivers are prime avenues for transportation, for sources of food, or for hydropower. The economic loss resulting from disease is particularly difficult to assess, even in societies where collection of complete and accurate demographic and social data is a well established practice. In many of the larger semi-arid countries, roads, railroads, or air networks provide extensive transport linkages at reasonable cost. However, this approach is prohibitive for some of the delta or savannah countries where dense jungle or hills impose serious physical obstacles to land transport or airport construction.

Some attempts have been made to assess the impact of weeds upon the economies of Florida and Louisiana. These may give some baseline for estimating losses in developing countries. Even as far back as the turn of the century, when the embryonic waterhyacinth infestation plagued Florida and Lake George was blocked by waterhyacinths for 40 kilometers, the estimated annual loss to the lumber trade alone was $55,000. Transport by water is still a vital factor in the economy of the Mississippi delta, since corn, rice, cane and cotton, together with fish, citrus fruits, salt, oil, lumber and other products, are all carried by water. The waterhyacinth invasion has thus had serious consequences, and it has been estimated that the annual loss incurred in Louisiana through the effects of the weed reached $35 million annually in recent years from damage to agriculture, fish and wildlife, navigation, drainage, and public health.

Aside from such roughly estimated direct economic losses, there are additional costs of deliberate weed removal and prophylactic measures for growth prevention. Such costs, which may amount to millions of dollars per year, are incurred just to keep the weeds under some level of control and to prevent further economic damage. Since 1959 the Corps of Engineers in Florida has received about $3.6 millon annually for waterhyacinth eradication programs in Florida. To this is added a 30 percent matching contribution by the state. That sum, however, is not all that is being spent. In addition, in 1969, the State of Florida spent $1.3 million for control efforts, and for fiscal year 1970, $2.5 million was requested by the Governor's Aquatic Weed Research and Development Committee because past control measures had not been very successful.

The economic losses estimated for the United States are, at best, rough estimates prepared by federal, state and local organizations concerned with budgets. While these estimated dollar losses represent the principal "hard" data available for any country, they are difficult to apply directly to situations in developing country with different labor and other costs and differing methods of estimating costs. For example, with regard to water transport, the large motorized barge systems used in the United States are less sensitive to cooling-intake clogging and propeller fouling than are the small, individual, and relatively crude river steamers and small barges powered by outboard motors so commonly used for transporting goods in developing countries.

In developing countries considerable sums are spent for weed control. In most instances at least one-half of the funds draw on scarce foreign exchange in paying for cutting apparatus and chemicals. Furthermore, needed labor for dam construction, flood control, fishing and transportation is often idled as the control programs are carried out or must be used for weed harvesting or destruction. The uranium and copper mining interests in the Congo Republic are known to have spent millions of dollars in this field. Egypt and the Sudan each spend about $1.5 million annually on control programs.

In the Sudan, an initial waterhyacinth control program involving technical advice, organization building, appropriate equipment and supplies, and control operations, was supported by A.I.D. from 1960 to 1964. At

the conclusion of the project, weed control activities employed 73 river craft of all types, 28 vehicles, 5 planes, 500 full time employees and 500 seasonal laborers. Control was effected largely by 2,4-D herbicide deployed from boats, land-based spray vehicles, and man-carried sprayers, as well as from aircraft under favorable weather conditions. This effort is continuing as noted above at an annual cost of about $1.5 million.

IV. COUNTRY SPECIFIC SITUATIONS

All available reports agree that aquatic weeds present "serious economic problems" for developing countries and that these problems will increase unless major control measures are undertaken. An attempt has been made to translate the weed menace assessments into very broad and quasi-speculative dollar equivalent losses. Several developing countries were selected as reasonably representative of those suffering economic losses which have a measurable impact upon their economies. Principal attention is directed to losses due to constraints on transportation and fishing which are the easiest aspects to address in a quantitative manner.

ZAMBIA

The inadequate road and railroad network of this landlocked country results in some dependence on short-haul water transportation on the Zambesi, Kaufue, Luangwa, and Chambesi Rivers; and on Lakes Tanganyika and Kariba for internal commerce. The presence of rapids and varying seasonal depths of water inhibit long-haul river transport, although logs and other freight are transported on the Zambesi above the falls at Livingstone. For at least eight months of the year these bodies of water are infested to some extent with aquatic weeds which restrict limited water-borne transportation.

The effect on internal commerce is significant. Considering agriculture, forestry, and fishing only, a two to three percent impact due to blockages of waterways and fishing areas means an internal loss of commerce of several million dollars since these industries account for more than $75 million of the country's total commerce. Weed clearance schemes, including reliance on imported equipment and materials, add another $750,000 to $1,000,000 in costs annually. In addition, schistosomiasis has shown a 10 percent increase from 1965 to 1969, which may be related to the presence of aquatic weeds.

THAILAND

The lower Mekong River Basin and other riverine regions in Thailand with their reservoirs, ponds, inlets, and channels, is infested with waterhyacinth, waterlettuce and waterfern.

Very roughly, about 30 percent of the Thai labor force is engaged in activities related to fishing and river transport. Fresh water fish serve as an important food source, with the rice fields and irrigation channels serving as good breeding grounds. Important river and canal networks are used for boat transportation around Bangkok and in the delta. There is evidence that weed concentrations are growing steadily and are beginning to have a noticeable influence on river transportation and fishing. In the Nam Pong and other reservoir areas the weeds move downstream where they accumulate in reservoir impoundments, and grow at an accelerated rate. While the economic consequences are difficult to quantify, order of magnitude estimates of the severity of the problem are presented below.

More than 80 percent of the rice crop, which earned $121,000,000 in foreign exchange in 1970, moves over the many waterways. Similarly, about 30 percent of the tin ore, tungsten ore, corn, sugar cane, rubber, and other export products move by water. The approximate value of such water-shipped products is about $300,000,000 per year. Assuming weed clogging reduces the mobility of boats and barges so that about two percent of the potentially marketable products not arrive at their destination at all or too late, then an annual loss of several million dollar accrues, including a substantial foreign exchange component.

The annual fresh water fish catch is valued at about $100,000,000. With the weeds interfering with spawning, a one percent loss could cost the economy $1,000,000 per year. The actual loss is probably greater since the weeds interfere with fishermen's gear and boats, and they probably also harbor fish predators.

With regard to costs of preventive action, it is estimated that initial herbicide weed control in the Pa Mong dam site area would cost about $50 per hectare and would be required for 10 percent of the reservoir area. An additional $40 per hectare per year is needed for one percent of the area to prevent weed encroachment. It is also estimated that a weed control research team costing $200,000 annually would be needed for 10 years to cover the Lam Pao, Nam Pung, and Nam Pong reservoirs. If the same control and prophylactic costs were to accrue for other than these waters, and assuming that about 1,000,000

hectares are threatened, then a probable initial cost would be several million dollars and annual expenditures would reach about $400,000.

Schistosomiasis is of growing concern in the Mekong region. The toll of this disease on the economy is not known. It is not unreasonable to estimate that the weeds could add one percent to the incidence of the disease which probably afflicts several million people. Assuming a 10 percent loss in productivity of the afflicted, it seems clear that from this point of view the weed menace is not insignigicant.

GUYANA

This small developing country suffers from both actual and potential aquatic weed infestations, mostly from the waterhyacinth. Guyana has 3700 miles of navigable waterways -- the only transportation routes in most areas. There are several potential hydroelectric sites. The effects of aquatic weed infestation can be seen along the coastal areas in reduced irrigation and drainage for rice and sugar cane and the interference with the transport of sugar cane fertilizer by punt in the waterways boardering the cane fields.

River fishing and forest products, which are heavily dependent on river transport, account for about 12 percent of the gross national product. The country, with a GNP of about $235 million, cannot afford interference with the flow of export foods and materials amounting to $121 million, with about 20 percent moved by river. A one percent weed-caused loss in river dependent exports seems conservative, given the extent of the weed problem. This means a $250,000 per year loss -- a modest but nevertheless serious item for a country with a trade deficit. Assuming that weed control would cost about $100,000 annually, a $350,000 per year loss accrues -- and most of it in foreign exchange.

Mosquito-borne diseases have been a long-time concern of the country. While malaria has been almost eliminated, weed infestations may cause a recurring control problem because the mosquitoes which breed in the weeds are very difficult to eradicate. Some increase in schistosomiasis has been reported, and it is likely that the increase is related to weeds.

V. COMMENTS AND CONCLUSIONS

1. Despite the difficulty of quantifying economic losses due to the weed menace, there is little doubt that direct losses exceed $100 million annually in the developing countries. Indirect losses may be far greater but they have neither been completely identified nor quantified in this preliminary survey.

2. The problems associated with aquatic weeds -- and particularly those related to navigation and schistosomiasis -- are growing as water patterns in developing countries are manipulated through dam construction and other man-made changes to the environment. Also, increasing sewage effluent and other by-products of an expanding population will probably add to the severity of the problems.

3. The magnitude of economic losses resulting from the presence of aquatic weeds and eradication and control costs in developing countries justifies further research and development on means for controlling the spread of weeds in these countries. Research should be directed toward (1) increased understanding of the causes of infestations, (2) improved measures for biological control, and (3) use of aquatic plants as a source of protein and means of removing pollutants from sewage and industrial wastes. Development should be directed toward (1) improving the effectiveness of mechanical, chemical, and biological control methods in a selected region where economic losses from aquatic weeds are particularly serious, and (2) identifying the optimum combination of these control methods for specific situations in that region.

4. The initial phase of a research and development program should define more sharply the types and extent of actual losses to aid in shaping subsequent phases of the program and defining the required levels of effort. This phase should also investigate the practical problems and costs of weed control, including the most promising contributions that could be made by research and development efforts related to control methods.

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