Potential Growth Of Aquatic Plants Of The Lower Mekong River Basin Laos-Thailand[1]

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ABSTRACT

Floating aquatic plants, waterhyacinth *(Eichhornia crassipes* (Mart.) *Solms)*, waterlettuce *(Pistia stratiotes* L.) and waterfern *(Salvinia cucullata* Roxb. ex Bory) were observed in large numbers in many different locations. It is probable that conditions for expanding growth of these species of floating aquatic plants will be favorable in the Pa Mong Reservoir. Plants of this type tend to form mats and bogs of intertwined vegetation which are substantially more dense than growth of the individual species. On this support many species including waterprimrose *(Jussiaea repens* L.) and watermorninglory *(Ipomea aquatica* Forsk.) grow and develop. Mechanical and chemical methods of control for these plants have been developed and used to a limited extent in Thailand. Treatment with herbicides of streams, ponds, and tributaries in the area upstream of the damsite prior to filling of the reservoir would provide a measure of preventive control. A schedule of annual maintenance application would also reduce the potential growth of aquatic plants above the dam. Natural and artificial irrigation channels should be constructed with level banks and suitable access routes so that mechanical methods of control such as chaining, dragging, mowing, and spraying treatments for aquatic plant control can be efficiently and easily done.

WATER RESOURCE DEVELOPMENT

There are four major river basins in Thailand. The central part of the country is a vast plain devoted mostly to rice cultivation and is irrigated from the Chao Phraya River. The Ping River flows from the northern highlands, and is the major potential of hydroelectric power at the present time. Irrigation and power development are in progress on the tributaries of the Mekong, but it is the Mekong River itself which has the greatest potential for power and resource development (4).

Studies involving technical problems relating to flood control, hydroelectric power production, and water resources development of the Lower Mekong River Basin were begun in 1951 by the United Nations Economic Commission for Asia and the Far East. It is in the context of this effort that the Pa Mong Project was envisioned and as a part of the planning program, an aquatic plant control survey to determine the nature and importance of aquatic plant infestations in the area of Pa Mong and ancillary hydrological projects downstream, was initiated. It is the purpose of the survey to assess the types of vegetation which might cause maintenance and operational problems, evaluate methods of dealing with these problems and recommend design modifications and/or further re-

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search that might be relevant to the multi-purpose water resource projects of the Lower Mekong River Basin. The survey is also intended to take into account physical, biological, ecological, and sociological factors of the environment for their effects on the growth and spread of equatic plants in terms of economic problems affecting normal operations.

The Agency for International Development (AID) has been extending technical assistance to the Mekong Coordination Committee for the Pa Mong and other projects of the Upper Mekong River Basin. The present concern of the committee has been the potential growth of aquatic plants. The Corps of Engineers Civil Works Directorate was asked to put together a survey party to cover the project area in North west Thailand and Laos, assess the types of vegetation, evaluate the problems that might be encountered, and recommend design modifications and/or research that would be relevant to resource development of the project. It is with this purpose in mind that a survey team was assembled, and the results of that survey are the subject of this paper.

GEOGRAPHIC LOCATION, CLIMATE, SOILS AND LAND USE

The proposed Pa Mong reservoir and project area lies along both sides of the Mekong River where it forms the boundary line between Laos and Thailand. The damsite is located 20 km upstream from Vientiane, Laos with one abutment in Laos and the other in Thailand. The Mekong River starts high in the mountains of the Tibetan Plateau and flows in a southerly direction through northwestern Laos, forming the boundary with Thailand for about 80 km on the north and for 720 km on the northeast, and then it forms the extensive delta through South Vietnam and finally empties into the South China Sea. The arable lands and potential service areas of the Pa Mong project include the Vientiane Plain in Laos and vast areas south and west of the damsite, extending into Thailand. The area of development has been tentatively estimated to include 1,600,000 ha of which about 33% of the land is now in rice paddy and upland field cultivation.

The climate of the project area is tropical monsoon. The winters are warm and dry while the summers are hot and humid. The rainy season begins in mid-May and extends to mid-October. The dry season begins in mid-October and extends through mid-May. Warm air masses move from the southwest in a counter-clockwise direction to produce the rainy season or southwest monsoon. Occasionally the air masses will shift sufficiently to the west to be displaced from the Indian Ocean and a period of drought follows. Flooding occurs when the monsoon rains are more frequent than usual at a particular place and time during the rainy season. Cold air masses move from the south over the mainland of China in a clockwise direction during the winter season, mid-October through February, and there is practically no rain. There is a followup period of transition when the Pacific air masses of the tropics produce a hot season with sporadic rain.

Soils of the Vientiane Plain and adjacent areas of Northeast Thailand are light brown alluvial deposits of fine sandy silt and clay, fairly well suited to rice culture. Under irrigation, two crops per year may be obtained, planted in August and January. Rice yields under present cultural methods are rather poor, averaging about 1.5 to 2 metric tons of rough rice per ha. Current research indicates that rice yield may be improved greatly by use of new varieties and better management including high levels of fertilizer, better water control and control of diseases, insects, and weeds. Upland soils are light sandy loams which tend to be droughty because of the porous subsoil structure and very low in plant nutrients and organic matter because of the tropical temperatures and high rainfall. Most of the common vegetables are grown locally. Papaya, bananas, and citrus are popular fruits. Field crops such as corn, sorghum, soybeans, sugarcane, sweet potatoes, peanuts and tobacco are grown alont the river. Pasture crops such as guinea grass, napier grass, coastal Burmuda, and sorghum are grown to a limited extent for grazing for dairy and beef animals. However, fish, seafood, chickens, and pigs are the major source of meat for the Laotian and Thai people.

ECOLOGICAL EFFECTS AND CONSIDERATIONS

Aquatic plant growth involves a very complex biological community from the most minute plant and animal microorganisms to highly specialized plant and animal life involving a long food chain. The ecological consequences of changes or control of particular populations must be evaluated in terms of the total situation. Both beneficial and harmful effects can usually be cited from the presence or absence of a particular aquatic plant (9).

Water-shading plants are highly objectionable for many situations because they form mats of floating vegetation which interfere with fishing, navigation, and recreational use of water as well as the operation of powerplants and crop irrigation. Sometimes their removal permits sunlight to penetrate lower strata to encourage bottom growth of submersed aquatic plants that are more objectional and harder to control than the original surface-covering plants.

Although submersed plants are popularly regarded as beneficial to fish by providing food and oxygen, most modern fishery biologists have observed that extensive aquatic weed growth is detrimental to fish production. Weeds provide sanctuary for small fish resulting in reduced production of larger fish, and they prevent efficient harvesting by impeding netting and boat operations. Rapid death and decay of submerged weeds through natural causes or weed control operations can cause fish kills by oxygen depletion accompanying the decay processes and the evolution of toxic quantities of hydrogen sulfide.

Planktonic algae, phytoplankton, form the basic photosynthetic link between the inorganic constituents in water and higher members of the food chain. When present in sufficient numbers the color of the water may be green, yellow, red and black depending upon the species. During the daytime these organisms remove carbon dioxide from the water and produce oxygen as a by-product of photosynthesis. At night, or if photosynthesis is blocked by shading, the process is reversed and oxygen in consumed. Phytoplankton are utilized by certain fish and other marine species and generally increase the yield of fish. Abundant growth of plankton algae with shallow water will shade the bottom and prevent the growth of many submerged vasular plants. However, these forms frequently clog water filters and many kinds interfere with the growing of rice. Most blue-green algae and many green algae produce odors or scums that are undesirable in potable waters and may be allergenic to swimmers. Some species are known to cause gastric disorders to persons consuming the water and toxic substances are frequently produced that kill fish, birds and domestic animals.

FLOATING AQUATIC PLANTS

Observations were made for aquatic plants along the Mekong River from Vientiane to Nakhon Phanom, along the Nam Ngum River waterways to the damsite, and over some tributaries of the Mekong River on the Thailand side. The Nam Pung damsite the Lam Pao reservoir, and the Ubolratana dam and Nam Pong reservoir near Khon Kaen were also surveyed. Field trips were made to the Phayao Reservoir in the vicinity of Chiang Mai, the Bhumibol Dam and Reservoir on the Ping River, and Bung Boropet Lake near Nakhom Sawan. This program was accomplished by use of a Dornier D-80 aircraft for the general survey and a Bell 47G-3B1 helicopter for close inspection and sampling. Motor vehicles and boats were also used as needed. Aquatic plants found during this survey are presented in Table 1.

Waterhyacinth, waterlettuce, and waterfern were easily identified from the arcraft by their color, growth habits and habitats, and large amounts of each were frequently observed during the survey. Dense mats of these covered open-water areas of sloughs, ponds and other lowland impoundments adjacent to the Mekong River and its tributaries. These areas of weed propagation function as continual sources of drifting vegetation that enters the river during times of flooding. This explained the presence of numerous small colonies of waterhyacinth and other floating weeds in the main course of the river at flood stage. Waterhyacinth could have come from as far upstream as Luang Prabang, because it is known to grow there as an ornamental plant occasionally fed to swine as it is in Vientiane. The presence of these weeds upstream of the Pa Mong damsite (e.g., the watersheds of the Mong, Wong and Loei Rivers) constitute a serious threat to the Pa Mong reservoir because of their capability of rapid spread from these isolated infestations during reservoir filling. Easterly winds would keep floating weeds away from the Pa Mong Dam itself, but any westerly winds, together with river currents, are likely to force mats of floating vegetation against the dam or its protecting boom. Such mats of weeds can become so densely packed that submerged portions decay, slough off, and sink to lower depths where they might enter penstocks and clog turbine screens. Fortunately, floating waterfern is not as large and aggressive as *Salvinia auriculata* Aublet., the species of waterfern that became so troublesome in Lake Kariba, Southern Rhodesia; nevertheless, floating waterfern was more frequently observed during the survey than any other floating weed, and it could become most important because it is so widespread. These smaller floating plants along with watervelvet and duckweed, which also were observed throughout the survey area, can pass through intake screens and clog the pumps and control structures of irrigation and drainage systems. They are also very troublesome to rice culture.

TABLE 1. SUMMARY OF AQUATIC PLANTS OBSERVED IN NORTHEAST THAILAND AND LAOS ACCORDING TO TYPE, COMMON NAME AND SCIENTIFIC NAME

Common Name	Scientific Name
A. Floating[a]	
Waterhyacinth	*Eichhornia crassipes* (Mart.) Solms
Floating waterfern	*Salvinia cucullata* Rox. ex Bory
Waterlettuce	*Pistia stratiotes* L.
Watervelvet	*Azolla pinnata* R. BR.
Duckweed	*Lemna* spp.
Watersnowflake	*Nymphoides indica* Kuntze
Waterlotus	*Nelumbo* spp.
B. Submersed[a]	
Blyxa	*Blyxa echinosperma* (Clark) Hook-f
Coontail	*Ceratophyllum demersum* L.
Waterfern	*Ceratopteris thalictroides* Brongn.
Chara	*Chara* spp.
Hydrilla	*Hydrilla verticillata* (L.F.) Casp.
Limnophila	*Limnophila heterophylla* Berth.
Grassy naiad	*Najas graminea* L.
Ottelia	*Ottelia alismoides* (L.) Pers.
Bladderwort	*Utricularia flexuousa* L.
C. Marginal[a]	
Alligatorweed	*Alternanthera philoxeroides* (Mart.) Griseb.
Arundo	*Arundo donax* L.
Coix	*Coix aquatica* L.
Sedge	*Cyperus difformis* L.
Sedge	*Cyperus procerus* Rottb.
Sedge	*Cperus rotundus* L.
Spikerush	*Eleocharis dulcis* (Burm. f.) Hanschel
Junglegrass	*Echinochloa colonum* (L.) Link
Fimbristylis	*Fimbristylis miliacea* (L) Vahl.
Lelang	*Imperata cylindrica* (L.) Beauv.
Rounded Isachne	*Isachne globosa* L.
Reedgrass	*Ischaemum rugosum* Salisk.
Waterprimrose	*Jussiaea repens* L.
Pepperwort	*Marsilia crenata* Presl.
Monochoria	*Monochoria vaginalis* (Burn. f.) Prest.
Torpedograss	*Panicum repens* L. f.
Waterpaspalum	*Paspalum scrobiculatum* L.
Giantreed	*Phragmites communis* Trin.
Watersmartweed	*Polygonum tomentosum* Willd.
Wildsugarcane	*Sachharum spontaneum* L.
Bulrush	*Scirpus grossus* L.
Cattail	*Typha angustifolia* L.

[a]Plant type.

SUBMERSED AQUATIC PLANTS

Although submersed aquatic weeds could not be identified to species from the air, dense infestations were observed as dark underwater patches in shallow portions of the reservoirs in northern Thailand (Lam Pao, Nam Pong and Nam Pung) and in static water sloughs and irrigations channels along the Mekong River and the rice growing areas of Thailand. Submersed aquatic plants are thin stemmed and profusely branched, and most are capable of rapid vegetative propagation from stem nodes, lateral buds, and stolons as well as by fruits and seeds. They are dispersed by water currents and waterfowl which carry parts of plants and seeds to new areas. They can become established and spread very rapidly as was seen in the relatively new project reservoirs. Once established, they are very difficult to control. Species known to be present in the project area include *Blyxa lancifolia* (*Clarke*) Hook f., hydrilla, coontail, limnophila, grassy naiad, and bladderwort. Bladderwort is regarded as an important food for fish which eat the insect-trapping bladders of the plant. Most of these species grow attached to the bottom mud, but masses of them can drift about underwater with currents and wave action, and they are likely to become prominent in the shallow areas of the Pa Mong Reservoir and in the distribution channels providing irrigation and drainage in rice fields and other agricultural lands. Submersed weeds have been found to impede channel flow as much as 97% and cause flooding as well as crop losses through poor irrigation and water management.

EMERSED AND MARGINAL AQUATIC PLANTS

Tall perennial grasses, such as coix, giant reed, and other herbaceous and woody emersed weeds were observed along the shorelines and banks of all rivers, lakes and channels surveyed. Bulrushes (*Scripus* spp.) bamboo (*Bambusa* spp.), and other shrubs were also observed among the predominant tall grasses on islands in the Mekong River and on its banks. These rooted erect plants grow in dense colonies by means of rhizones, stolons or runners, and they are capable of rapid encroachment into open water from the margins of lakes or reservoirs covering large areas as they build out from the shore and collect debris among their intertwined root systems. Decumbent creeping species such as waterprimrose, watermorningglory, and watersmartweed were also found to have formed floating islands with mats of floating weeds in the sloughs and impoundments of the area surveyed. Marginal vegetation would not be expected to become serious until after reservoir filling and construction of irrigation and drainage channels of the agricultural distribution system. Seasonal fluctuations in water depths would tend to keep the reservoir perimeter clear of marginal vegetation at first, but aquatic grasses and shrubs are likely to become established eventually along gently sloped margins of bays protected from wave action as observed at the Nam Pung, Lam Pao and Bung Borapet reservoirs in Thailand. Water primrose and creeping perennial grasses such as waterpaspalum were the most frequently observed emersed weeds growing along the banks and often across irrigation and drainage channels in the Ping and Chao Phraya River plains in Thailand, and these or others with similar growth habits are likely to be continuous maintenance problems along the distribution systems of the Pa Mong Reservoir.

AQUATIC PLANT CONTROL

The present survey indicated that aquatic plants generally common to tropical areas around the world (5,6, 10,11,13) are present in substantial numbers along the upper reaches of the Mekong River. There seems to be an unlimited source of these plants in the rice paddies, small ponds, and irrigation channels of the tributaries in the reservoir area. During flood stage it was observed that these plants are uprooted and moved downstream. It is estimated that 10% of the reservoir area is highly infested with these plants, principally waterhyacinth. As a measure of preventive control, this area should be treated with (2,4-dichlorophenoxy)acetic acid (2,4-D) immediately prior to filling the reservoir. Spraying by aircraft to reduce the potential population would be particularly feasible at this time because there would be no involvement with crops or probable uses of the water. Waterlettuce and waterfern which are also present in local areas are not readily controlled by rates of 2,4-D commonly used. Spot treatments of waterlettuce and waterfern with 6,7 dihydrodipyrido [1,2-*a*:2',1'-*c*] pyrazindiinium ion (diquat) at this time would be very effective. Most submersed aquatic plants are also controlled by diquat. Marginal aquatic plants are not contolled by either of these herbicides, but would be controlled in the initial stage by flooding, and would not likely be a problem until after the reservoir had been in operation for some time, and then, only in the shallow areas.

The principle of preventive control should also be applied after the reservoir is in operation as a repeated maintenance schedule. At the Bhumibol Dam, boats are used to spray waterhyacinth that drifts in during high water and flood stage of the Ping River. According to the Yanhee Electric Authority, which has maintenance responsibility, annual spraying with 2,4-D costs approximately $17,000 to cover approximately 400 ha at a concentration of approximately 2.25 kg of 2,4-D acid/ha. It is estimated that an annual maintenance schedule for the Pa Mong reservoir would require treatment of approximately 1% of the surface area.

Other measures of preventive control should be applied to the Pa Mong project if feasible. Clearing of trees and brush around the perimeter of the reservoir and deepening shallow areas will reduce marginal aquatic plant problems. Lining of main irrigation channels will substantially reduce aquatic plant growth in the irrigation system. Tops of channel banks should also be leveled and surfaced so that mechanical methods such as chaining, dragging, mowing, or spraying can be easily and efficiently done. Suitable gates to permit "drawdown" of water in irrigation channels will also facilitate control of marginal and submersed aquatic plants. It may also be economical to fence reservoir areas to permit grazing on marginal aquatic plants by cattle or sheep. Where water buffalo deteriorate the dikes of the channel, these animals should be fenced out.

Various mechanical devices are available for control of aquatic plants, including weed saws, cables draglines, and barges or boats equipped with mowers, airjets, waterjets, etc. The advantage of mechanical control is that it involves very little direct hazard to fish, wildlife or humans. However, such methods are usually very inefficient and uneconomical. Usually they give only partial control and must be repeated at frequent intervals. Sometimes mechanical methods only break up or tear the weeds apart and the loosened vegetation, if not properly disposed of, may clog gates, pumps and syphons, or cause new colonies of weeds to grow downstream. Cables or booms can be used to control waterhyacinth and other floating aquatic plants by placing the boom at an angle to the streamflow, floating at the waterline to divert the vegetation to the side where it may be removed mechanically. At the Bhumibol Dam, waterhyacinth is pushed to shore by boats or held there by cables during high water level so that it is killed by drying when the water level drops and the stranded vegetation and trash is burned as soon as possible. Submersed aquatic plants can be controlled mechanically in irrigation and drainage channels by drawing down the water for 2 or 3 days. The thin-leaved submerged aquatic plants dry quickly when exposed to the air. However, some nodes and subsoil propagules commonly survive this treatment, and it must be repeated periodically for vegetation control. Some emersed and marginal aquatic plants can be controlled by cutting the vegetative growth at drawdown so that they become sumberged and killed when the water level rises again.

CHEMICAL CONTROL

Control of aquatic plants with herbicides is usually easier, faster, and longer lasting and frequently cheaper than mechanical control (7,9). Treated plants die in place where they decay and dissipate without causing difficulties in the distribution system. Most of the new aquatic herbicides will not injure crops or fish when used correctly, but some of the older materials such as acrolein or armotic solvents are toxic to fish. Copper sulfate pentahydrate ($CuSo_4.5\ H_2O$) is the safest, most effective, and inexpensive and most extensively used algicide. Periodic treatments with copper sulfate at 10 to 14-day intervals at concentrations up to 1.0 ppmw control plankton algae in non-flowing water. Concentrations up to 1.0 ppmw are harmless to most species of fish; higher concentrations are toxic. A problem of algae at the damsite may involve small pipes and fittings in the cooling systems of transformers or other mechanical and electrical equipment. At the Bhumibol Dam, a solution of hydrochloric acid and rust inhibitor is used to clean these parts periodically. Several herbicides are used for control of rooted submerged plants and non-rooted vasular plants, including diquat and 7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid (endothall). These herbicides are rather expensive and must be applied judiciously. Repeated applications of 2,4-D at 2 to 4 kg ai/ha with water carrier provides a satisfactory control of waterhyacinth and water lily (*Nymphaea* spp.). Diquat is an effective herbicide for control of free floating species such as duckweed, waterlettuce, and waterfern. Rates of 1 to 1.7 kg/ha are sufficient. Applications should be made as a foliar spray with surface equipment in 1650 to 2200 L of water/ha or with aircraft at 80 L/ha. Most broadleaved, emersed, herbaceous, woody species can be controlled by single or repeated applications of 2,4-D, 2 (2,4,5-trichlorophenoxy) propionic acid (silvex), or (2,4,5-trichlorophenoxy)acetic acid (2,4,5-T) at 2 to 10 kg/ha. These include alligatorweed, smartweeds, and waterprimrose. The herbicide 3-amino-*t*-triazole (amitrole) or a mixture of amitrole plus trichloroacetic acid (TCA) at 4 to 18 kg/ha or 2,2-dichloropropionic acid (dalapon) at 5 to 20 kg/ha will control marginal aquatic grasses, sedges, and cattail. The herbicide should be applied in 2500 L/ha with surface equipment and 120 L/ha with aircraft. Treatments for floating and marginal species are made in terms of surface area and submersed species in terms of the volume of water treated.

BIOLOGICAL CONTROL

Techniques for control of aquatic plants with biological agents in tropical climates are relatively well developed at the laboratory level but few are or have been applied in the operational sense (1,2,3,8,12). Their aplication for aquatic plant control in Thailand would require a research and development program on the lakes and reservoirs as they exist in Thailand or may be constructed in the future. Waterhyacinth is known to be susceptible to attack by a flea beetle (*Acigona ingnitalis*) in South America. Host specificity studies are in progress in Argentina, Uruguay, and Trinidad. Other potential parasites include a moth (*Cornops longicorne*), a weevil (*Neochetina* spp.) a mite (*Orthogalumna terebrantis*), a borer (*Arzama densa*), and a grasshopper (*Gesonula punctifrons*). These aquatic plants parasites should be studied specifically for control of waterhyacinth in Thailand. Waterfern is known to be susceptible to attack by a number of different insects including a leaf miner (*Crytobagous singularis*), an aquatic grasshopper (*Paulinina acuminata*), and a moth (*Samea multiplicalis*). These and possibly other plant pathogenic organisms should be studied on floating waterfern in Thailand. Waterlettuce is susceptible to biological attack by a moth (*Samea multiplicolio*) and a snail (*Marisa cornuarietis*).

HERBIVOROUS FISH

Biological control of aquatic vegetation is possible by use of certain species of herbivorous fish, (6,9,11). Nile tilapia (*Tilapia nilotica*) and congo tilapia (*T. melanopleura*) are known to eat specific aquatic plants. Climate conditions in Thailand could favor the use of these species. Another species (*T. zillii*)which has been used for control of vallisneria (*Vallisneria* sp.) in Russia may be useful for aquatic plant control in Thailand. The white amur (*Ctenopharyngodon idella* Val.) is known to be effective for control of most aquatic vegetation and should be studied for aquatic control in Thailand. Research indicates this species would be compatible with local species and has shown considerable promise of success for control of submerged weeds. The silver carp (*Hypopthalmichthys molitrix*) is known to feed exclusively on planktonic algae and could probably be used to control algae blooms. The white amur, the silver carp, and local varieties like *Pontius* spp. and some filamentous algae feeders show promise for control of submerged aquatic weeds in Thailand.

Research on the culture of fish in the irrigation system is currently being conducted at the Agricultural Center, Khon Kaen, Thailand by Dr. Gerald D. Ginnelly and Mr. Suin Rothcharug. A related project to study the stomach contents is being conducted at Bung Borapet Fisheries Station, Nakhon Sawan, Thailand by Mr. Camron Phothephitalssa and Mr. Suchin Tongonsee. Basic studies on fish culture are also being conducted by the Department of Fisheries, Gasetsart University, Bankok, Thailand. These studies suggest that herbivorous fish may be added to the fish population for aquatic plant control and that extensive growth of aquatic plants do reduce the commercial production of fish. From the general review of the different possibilities for control of aquatic plants it is apparent that there is a real potential for biological control but that practical applications require additional research and development in the target area.

FEEDSTUFF FOR LIVESTOCK

Aquatic plants, including waterhyacinth, waterlily, waterlotus, waterchestnut (*Trapa bicornis*), watermorningglory, and many others, are used for human and animal food throughout the world (9,11.) Indeed, food and ornamental uses of these plants account mainly for their wide distribution. Waterhyacinth, for example, was brought to Java from its native South America by the Dutch, because its blossoms reminded them of cultivated flowers in Holland. It was introduced from Java into Thailand during the reign of King Rama IV in the 1860's and can be found in the numerous waterways throughout the country. Because it is usually at hand, waterhyacinth is used to feed swine, water buffalo, and cattle in Thailand and other Asian countries, and these uses have often been suggested as means of waterhyacinth control. Water hyacinth has limited food value (protein content is 8 to 12% of dry weight), but its water content is too high for direct consumption and the cost of drying and transporting to dryers or feedlots precludes its commercial use for animal feed in quantities sufficient to control its growth and spread. The same would be true of the other noxious aquatic plants such as waterlettuce and waterfern.

CONCLUSIONS

Waterhyacinth, waterlettuce, and waterfern were frequently observed in the lakes, ponds, and tributaries of the upper reaches of the Mekong River. These species are known to have caused serious problems to various water impoundments and tropical regions of the world. They are likely to cause the same problems in the Pa Mong reservoir because they are moved downstream, are accumulated in reservoir impoundments and have a rapid rate of growth in the area of accumulation. Submersed and marginal aquatic plants are likely to become a problem in the channels and ditches of the distribution system, below the damsite. Mechanical and chemical methods are the only means of control currently available and should be applied (with due caution) to prevent a large build-up in the population of these plants.

Biological control of the above species requires a specific research and development program in the target area before operational applications can be made. A survey of potential sites suggests that a research team composed of a weed scientist, a research entomologist and a research pathologist located at the Agricultural Research Center near Khon Kaen would be desirable. In this area, three reservoirs, Lam Pao, Nam Pung and Nam Pong are suggested as testing sites for the development of suitable weed control methods.

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