WATER WEEDS OF THE MEKONG DELTA

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A Bibliographic Survey

by

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INTRODUCTION

At the request of the Amphibious Research Command, TRECOM, Ft Eustis, Va., in cooperation with the Army Research Office-Durham, is submitted herein a bibliographic survey of the aquatic vegetation of the Mekong Delta. The survey was made in order to compare the aquatic vegetation of Viet Nam with that in certain places in CONUS which are being used to test boats and their reaction with water weeds. The senior author has observed exhaustive boat testing in Walker's Lake near Lanexa, Virginia. The margins of Walker's Lake present a challenging array of water weeds.

Since vegetation is a function of the environment a brief environmental introductory section is included pertaining to geography, soils and climate. Aquatic vegetations of two remotely distant areas within the same environmental parameters will usually show more similarities than terrestrial vegetations of the same two areas.

Illustrations of thirty-six Vietnamese aquatic plants are included, many of them borrowed from a survival manual for Viet Nam published earlier (Duke, 1963b). These were prepared by Mrs. Peggy Duke. The figures are framed in facsimile punch cards according to the principles outlined in the reports on El Real, Panama (Duke, 1963a and Duke and May, 1963). Using these simulated punch cards allows a great deal of botanical description in a minimum of space. An explanation of the coding appears in Fig. 15. In addition to the efficient disposal of descriptive material, the cards could be useful in identification if all the aquatic plants were so coded. For example, if a novice found a tree with buttresses, stilt roots and pneumatophores, he could by sorting for these three characters pull out an illustrated card of _Bruguiera_. No other Vietnamese aquatic plant has all these characters. Or if he found an unknown with whorled toothed leaves and sorted for these characters, he would retrieve two cards, those of _Ceratophyllum_ (Fig. 14) and _Hydrilla_ (Fig. 14), and could tell by looking at the illustrations which one he had. Similarly, if someone had to write up a paper on the aquatic plants of Cuba, he could drop all the cards punched for the West Indies. Eleven of the thirty-six species illustrated herein would fall out and he would have a good start on his research into the Aquatic Vegetation of Cuba. Or if intelligence personnel found a reference to a particular plant genus about which they wanted to know more, they could drop the card or cards conforming to the numerical coding for that genus. The numerical coding follows that of Dalla Torre and Harms used in most major botanical institutions. It would not be a difficult assignment to prepare illustrated punch cards for all of the genera in Dalla Torre and Harms provided specimens of all were available. Using page size punch cards all important military information could be included. Such a task would probably require about twenty thousand man hours for research but would save much more time than this. For field identifications, transparent punch cards such as those outlined by Duke (1963b) would be quite useful.

Mr. R. D. Newnam furnished the cover, an abstract drawing of a Nipa Palm Swamp.

It should be emphasized that this is a survey of the literature and certain references have been vital to this compilation. They are marked with an asterisk in the bibliography. Not all references in the bibliography have been directly cited in this search of the literature but they are included for future reference. Mr. Phung Trung Ngan, former student of the senior author, and an affiliate of Vu Van Cuong, (1960), writer of the most important source reference, has been most helpful both in seminars and conversation.

GEOGRAPHY

According to the University of Michigan Report (1962) the Mekong Valley is a broad lowland to as much as 200 miles wide which extends through eastern Thailand to the Mekong Delta. It is separated by a low hilly divide from the Chao Phraya Valley of Thailand. To the northeast of the Mekong Delta begins a succession of eroded plateaus with some high peaks known as the Chaine Annamitique, which separates the Mekong Delta from the Tonkin Lowland. Toward the Mekong Delta, the Chaine is an undulating upland about 50 miles wide between the South China Coast to the east and the Mekong Drainage System to the west. Surface elevations range from 300 to 600 feet with some individual peaks reaching 2400 feet. Local relief of the surface varies from 150 to 300 feet and slopes are about 3 to 4 percent.

The Mekong Delta extends southward from the Cambodian Mountains for about 100 miles to Cape Cambodia (Point de Camau), the southern tip of the Indo-China Peninsula, and then northeastward along the South China Sea. It extends inland at least 400 miles in places. It is a level, featureless lowland subject to disastrous floods and intricately dissected by tributaries of the Mekong, canals, meanders, and drainage and irrigation ditches. Van Cuong (1960, p. 331) describes an aerial view of Saigon "Saigon vu d'avion apparait comme une tache tentaculaire, bigarree, au milieu d'une entendue verte quadrillee en damier regulier par les diguettes." The western portion of the delta, largely occupied by mangroves and fresh water swamps, is permanently flooded for 15-20 miles inland. The eastern coast is fringed with a mangrove belt usually two miles or more wide. Trafficability and penetration would be very difficult. The Mekong Delta is comprised of 93.4 percent plains (under 600 feet of relative relief), 6.4 percent hills (600-2000 feet of relative relief) and 0.2 percent low mountains (2000-3000 feet relative relief).

Along the South China Sea Coast, there are wide delta plains at the mouth of the Mekong (to ca. 11°N Lat.). North of this in the region of the Chaine Annamitique the coastal zone is hilly with relatively narrow plains with hilly spurs projecting as headlands. Many beaches are covered with blown sand or moving sand dunes in parallel rows. On the basis of this information may be projected the occurrence of four plant communities. Delta plains will be fringed with mangroves. Hilly spurs projecting into the sea will probably support a Coccoloba-Barringtonia community analagous to the sea-grape community reported by Duke and May (1963) in Panama. Sand dunes which are more prevalent on the coast to the north of the Saigon River will support the pes-Caprae community. Moving dunes are often vegetated with the Australian Pine, *Casuarina equisetifolia*. Of these, only the mangrove community can by any stretch of the imagination be considered an aquatic community, and plants of the mangrove have their feet wet only at high tides. Mangroves are important to both aquatic and terrestrial mobility. According to Van Steenis (1958) "Along certain mud shores, notably the west coast of Malaya and the east coast of N. Sumatra, there occurs a narrow strip of sand beach on the mud where the surf strikes the coast. This fan of sand is sometimes slowly rolled landwards while the mangrove mud is exposed on the seaward side: in fact here we have simply a narrow belt of sand piled up on top of the mangrove mud, the mud being never more than a few feet below the surface of the sand at the top of the beach...From the air the foreshore of such a coast with a sand beach might be interpreted as sandy, though the sand represents only a very narrow strip of sand veneer. This misinterpretation, I am told by Mr. Corner, has proved to be disastrous in landing attempts of tanks by Allied Forces on the west coast of Malaya at the end of the last world war, the tanks finding a soft mud instead of a firm, sandy bottom."

The west coast of Viet Nam is rather different from the east coast. The 5-fathom line averages about 10 miles off-shore, the 10-fathom line nearly twice as far. On the east coast, the 5-fathom and the 10-fathom contours are usually less than a mile offshore. Some of these data from the University of Michigan Report are included in Table 1 and a map of part of the coast is presented in Fig. 2.

	LOCATION	COORDINATES	5-FATHOM CONTOUR	10-FATHOM CONTOUR
WEST	Nui Ong Thoa	10°08'N 104°38'E	19 miles	Very Far
	S. of Les Mamelles	9°02'N 104°48'E	7 miles	13 miles
	Xam Mui	8°38'N 104°43'E	4 miles	5 miles
EAST	Ap Haa Thanh	9°40'N 106°40'E	5 miles	7½ miles
	Cap Saint Jacques	10°20'N 107°15'E	Very Close	4 miles
	Pointe de Ke Ga	10°40'N 108°00'E	¼ mile	1 mile

TABLE 1: OFFSHORE DISTANCES OF THE FIVE- AND TEN-FATHOM CONTOURS IN VIET NAM

The Indochinese Coast of the Gulf of Siam has 26.3 percent flat coastline, 5.3 percent sandy, 17.8 percent hilly, 49.5 percent mangroves and 1.1 percent swamp. On the other hand, the Indochinese Coast of the South China sea has 6.8 percent flat coastline, 14.6 percent sandy, 12.0 percent hilly, 9.4 percent rocky offshore, 4.9 percent cliffs, 27.0 percent sand dunes, 22.1 percent mangroves, and 1.1 percent swamps and 2.1 percent coral reefs.

According to Health Publication No. 5 (Walter Reed, 1960), water transportation is very important in South Vietnam, most freight being water-hauled. Almost all imports and exports are carried by boat through the Port of Saigon. The Mekong River provides the main inland waterway to South Viet Nam and even to Phnom Penh in Cambodia. The river accomodates boats with 14-foot draft in all seasons. Launches and barges are extensively employed along the coast while in the canals and smaller streams of the Mekong Delta junks and sampans are used.

There is no shortage of weeds in these inland waterways and there are several noxious animals. There are at least 10 poisonous water snakes of the family Hydridae. Water leeches occur but they are not as much a problem as terrestrial leeches, the bites of which may be followed by ulcerating infections. In the coastal waters are sharks and several kinds of fish capable of injecting poisonous stings, sometimes fatal. There are also marine mollusks which can inject painful or fatal stings, while in the inland waterways and rice paddies are snails which play an intermediate host role in the snail fever schistosomiasis. In brackish estuaries occur large crocodiles which may attack and kill people, there being a few fatalities each year. Several species of disease-carrying mosquitoes also breed in inland waterways and rice paddies.

Zanobetti (1963) discusses some interesting features of the Mekong Drainage System. In the dry season fresh water flows into it from the remote Great Lake, but in the rainy season the flow is reversed and water flows into the lake from the flooded river. The Tonle Sap project, as outlined by Zanobetti, would erect mobile barrages in the Tonle Sap between the Great Lake and the Mekong, perhaps in the vicinity of Kompong Luong. By controlling the flow, to and fro, irrigation, desalinization and energy could be considerably increased. The dry season upsurge of saline waters in the Mekong would be alleviated or diluted. This would of course alter the distribution of aquatic plants and animals in the Mekong and its brackish tributaries.

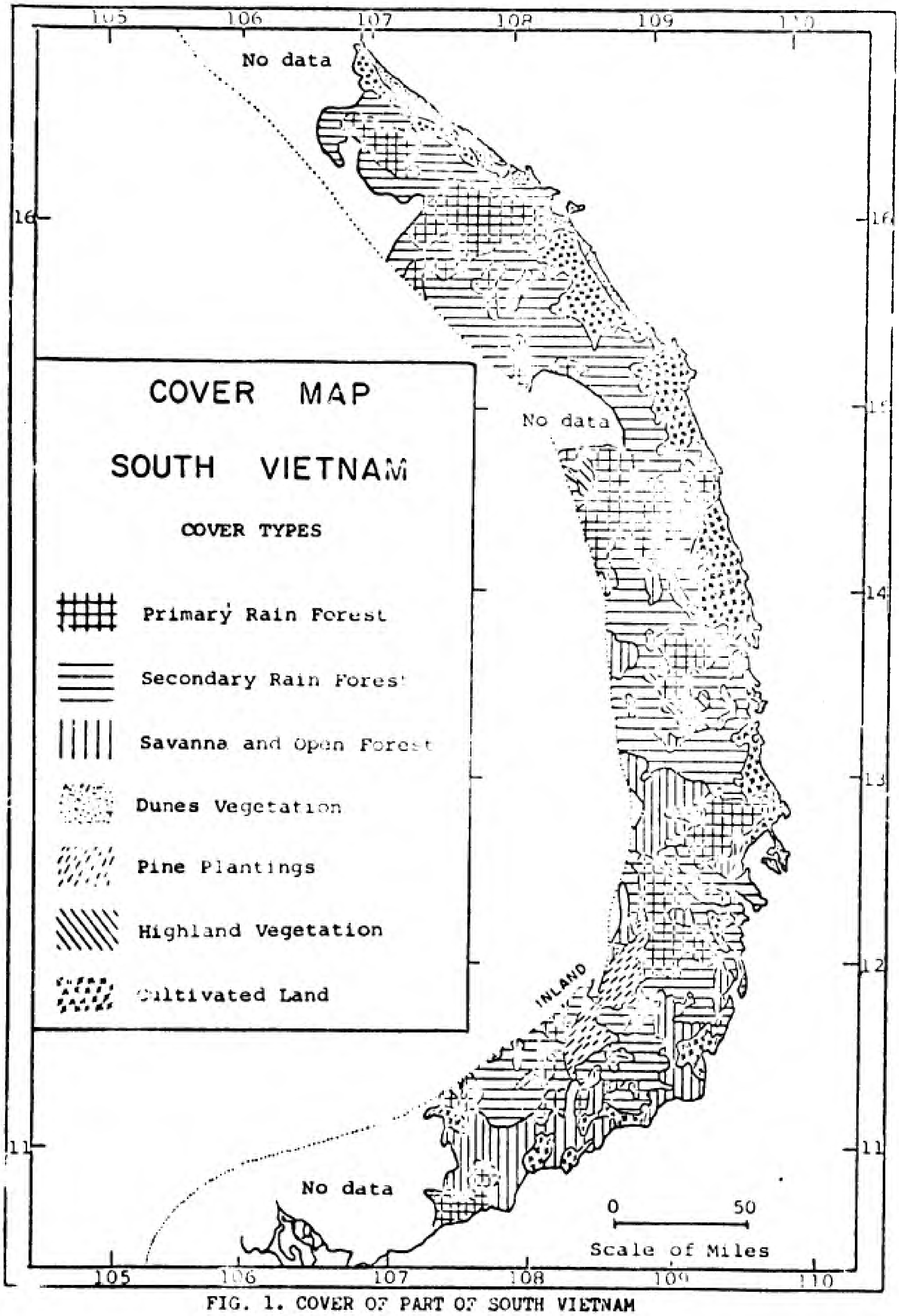


FIG. 1. COVER OF PART OF SOUTH VIETNAM
(After Univ. of Mich.)

SOILS

Soils of the Delta are largely alluvial and would be poorly trafficable except during the dry season. The plateaus and hills would of course not consist of alluvial soils but rather of a complex of red and yellow podsols and litnosols. Sands and gravels would be more frequent along the coast line approaching the Chaine Annamitique, and trafficability would be better here, soilwise and vegetationwise. Moorman (1960) divided the soils of Viet Nam into 25 categories. Six classes of alluvium are differentiated on basis mainly of acidity, and one type called "alunees" has such a heavy concentration of iron and aluminum sulphates as to be prohibitive to the growth of certain plants, e.g., rice. Such swamps support a particular group of aquatic plants which might be useful as indicators.

Soils of the Mekong Delta are rather rich in nitrogen and potash but rather poor in lime and phosphoric acid. It is pointed out by Van Cuong (1960) that the appellation ("alunees") is not a good one because iron replaces the aluminum and soda may replace potash. Iron sulfate is always present so the soils cannot be properly called bauxitic. Perhaps lateritic is a better term. Toxicity of the soils is due not only to sulfate ions but to high concentrations also of iron and aluminum. Distribution of these toxic laterites is outlined in Fig. 2.

For about ten miles inland from the coast of the delta, the soils are tidal saline muds supporting mangrove and back-mangrove vegetation. On the western coast is an extensive area of mixed peat and mud, one of the few places in the tropics where peat accumulates, and perhaps analagous to similar situations in Ceylon and Surinam. Such soils are probably quite acid. As a whole, the delta soils are soft, dark, level and wet.

In grading into the Chaine Annamitique, there is a transitional area of flat to rolling topography bearing uplifted podsolized alluviums and reddish latosols derived from various sedimentary and basaltic rocks. In the Chaine is a complex of red and yellow podsolic and lithosolic soils which extend on into North Viet Nam.

CLIMATE

South Viet Nam is a tropical, monsoonal country, and the Mekong Delta is a good climatic analogue of the Panama Canal Zone. (Thompson, 1958). As shown in Fig. 2, the Mekong Delta is nicely circumscribed by weather stations at Hatien, Poulo-Condore and Cap St. Jacques. These stations are closely analogous to the Canal Zone in the following respects:

1. Mean temperature of the warmest month 77-85°F
2. Mean daily maximum temperature of the warmest month 88-89°F
3. Mean temperature of the coldest month 76-78°F
4. Mean daily minimum temperature of the coldest month 72-75°F.

In the Mekong Delta the mean daily temperature range of the warmest month is 11-13°F as compared with 8° at Cristobal and 16° at Balboa Heights. The mean monthly precipitation of the wettest month is 8.9-15.7 inches as compared with 11 inches at Balboa Heights and 22 inches at Cristobal. The number of wet months is 7-9 as compared with 9 at Balboa and 10 at Cristobal. The monthly mean relative humidity of the driest month is 74-82 percent as compared with 75 percent at Balboa and 77 percent at Cristobal. In the Mekong Delta,however, the mean wind speed of the wettest month is considerably higher than at the Canal Zone Stations, emphasizing the monsoonal nature of the Mekong climate.

The monsoonal system is evident in all of southeast Asia and coupled with topography causes a great variation in local precipitation. In general the monsoons blow into Asia in the summer (June-Aug.) from the south and southwest, and in winter (Dec.-Feb.) blow out of Asia from the north and east. Winds from the southwest in June through August bring heavy rains to the west coasts while winds from the northeast in Dec.-Feb. bring dry weather. According to Chamber's data (1961), the Mekong Delta embraces rainfall regimens of 1-20 inches in the Dec.-Feb. period and 20-50 in the June-Aug. period. This would explain to some extent the seasonal changes in rice production. Fig. 10 shows a rice calendar modified from Van Cuong (1960) for the environs of Saigon and Fig. 9 a map showing the system followed in various parts of old Indo China (after U. Mich. 1962). The calendar for the Saigon Area is based on the Single Transplantation system.

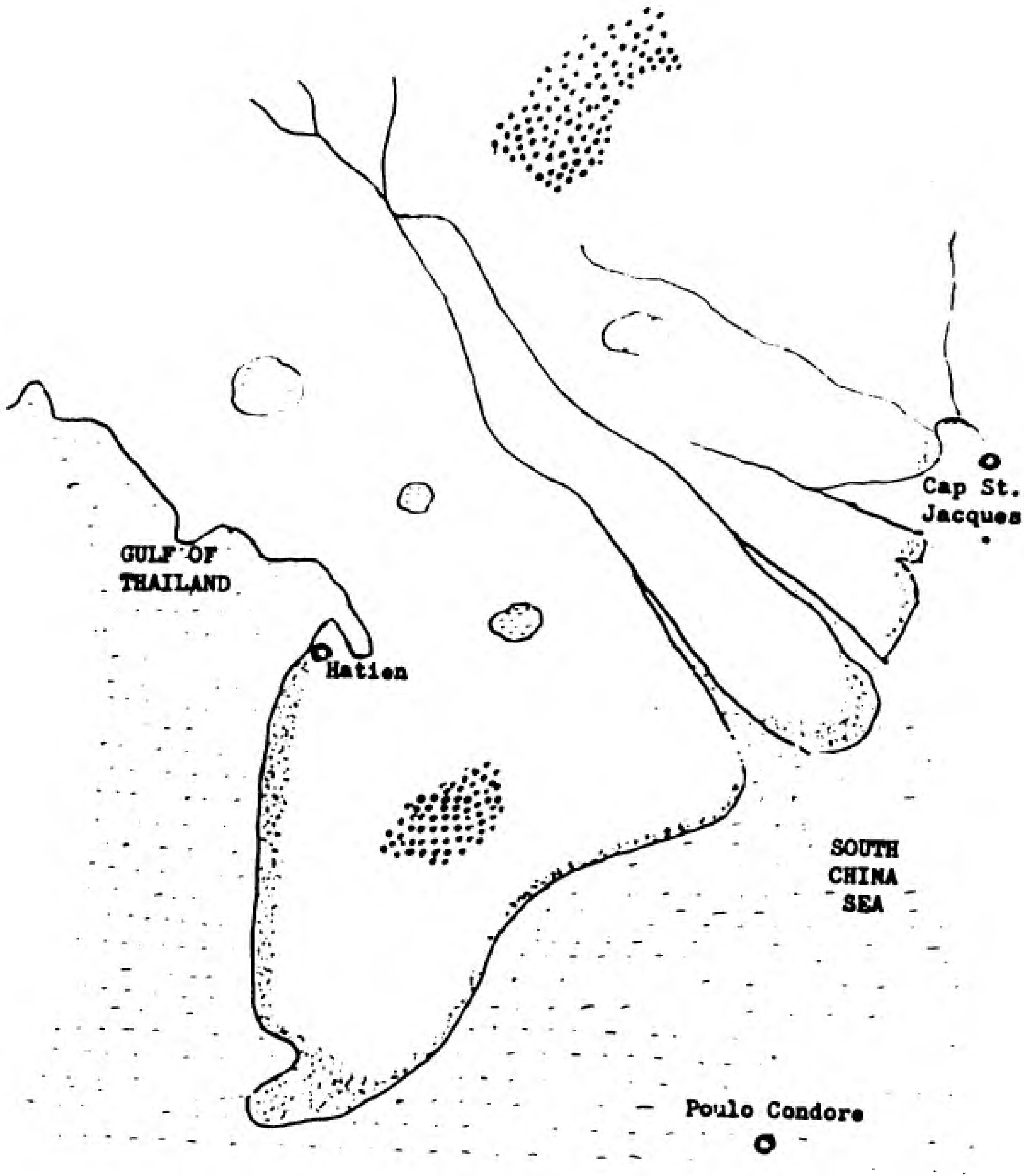


FIG. 2. MAP OF THE ORIGINAL VEGETATION OF THE MEKONG DELTA
Water   Lateritic Swamp
Mangrove   Swamp Forest (F.W.)
Weather Station

CLASSIFICATION OF AQUATIC PLANTS

Aquatic plants are known as Hydrophytes, generally broken down into three categories:

1. Limnophytes: Plants of open water
2. Helophytes: Marsh Plants
3. Hygrophytes: Swamp Plants.

Aquatic plants are also broken down into categories according to their salt tolerance so that there are marine, brackish and fresh water species.

True aquatic plants or limnophytes are furthermore often classified as to their relation with the surface of the water. Here exist three intergrading categories:

Immergent or submerged plants: Plants completely underwater at all times.

Floating Plants: The whole plant or parts of the plant float at the surface. This can be further subdivided into anchored floaters which are rooted in the bottom like water lilies (Fig. 12) and free floaters which are not attached to the bottom. The reactions of these two types with boats may differ. Anchored floaters usually have rope-like stalks going down to the bottom which tend to wrap about propellors. Free floaters lack these parts but may have tenuous masses of roots hanging down below them which can react in the same fashion with propellors. A special category of free-floaters are the minute duckweeds which are so small as to be insignificant to boats except that they have been known to clog up cooling systems. Larger free-floaters such as the water hyacinth and water lettuce (Fig. 13) often form dense colonies which may slow down or stop boats by their mass alone.

Emergent Plants: Part of the plant is in the air above the water. All of the marsh and swamp plants (helophytes and hygrophytes) are emergent and to this category belong most species of the mangrove, sedge, rice paddy and palm swamp communities outlined below.

The tendency among ecologists is to group plants that frequently occur together into units which may be termed communities. These are merely groups of plants which tend to occur wherever certain ecological factors exist. Aquatic plants of the Mekong Delta may be grouped into the following communities:

1. Sea Grass Communities or "Submarine Meadows": Strictly salt water submerged species.
2. Mangroves and Back Mangroves: Mostly shrubs and trees shallowly submerged in saline or brackish waters with high tides.
3. Palm Swamps: Tall herbs and shrubs associated with the Nipa Palm and inundated by brackish water at high tide and by fresh water in floods.
4. Sedge Marshes: Tall sedges, grasses and forbs inundated by fresh or slightly brackish waters periodically or temporarily.
5. Rice Paddies: Cleared and Cultivated Sedge Marshes and Fresh Water Swamps. Artificially inundated in the rainy season and drained in the dry season.
6. Water Lily Community: Anchored floaters in fresh or slightly saline waters.
7. Duckweed Community: Free-floaters in fresh or slightly saline waters.
8. Bladderwort Community: Submerged attached or detached plants in fresh or slightly saline waters.
9. Fresh Water Swamp Forests: Periodically Inundated Forests in the Rainy Season.

Species listed by Van Cuong for Communities 3-7 are included in Table 5. The Fresh Water Swamp Forests, composed of *Dipterocarpus*, *Melaleuca*, Annona, etc., are not of concern to hydrotrafficability and will not be further treated here, since they are not generally water routes and would be only periodically inundated during the rainy season.

Fig. 3 depicts the vertical distribution of aquatic plants in relation to high tide levels about Saigon.

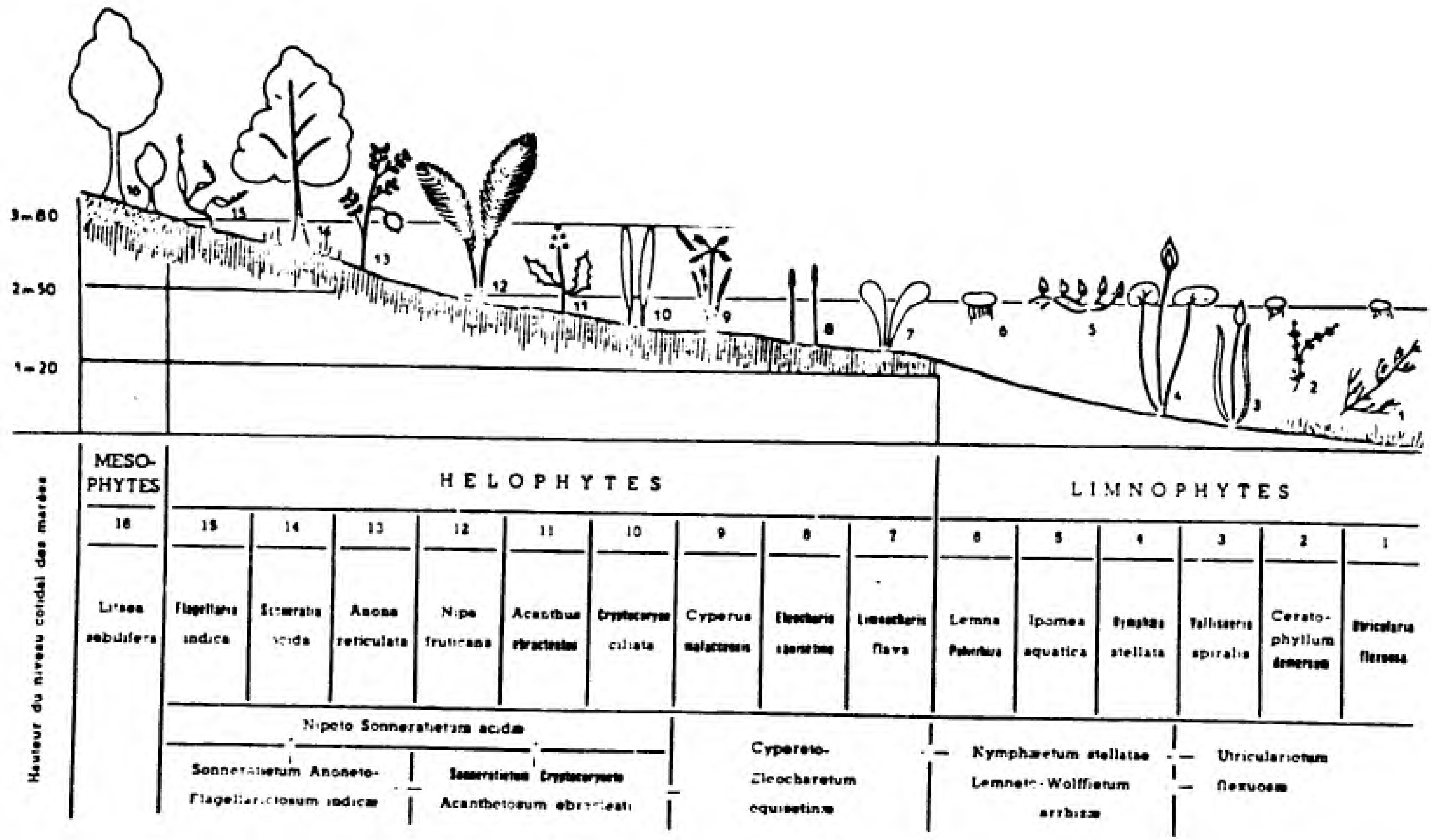


FIG. 3. VERTICAL DISPOSITION OF AQUATIC PLANTS
(After Van Cuong)

SEA GRASS COMMUNITY

Submerged in salt water, usually in protected places where tides and currents are not so strong, will be thickets of grass-like plants called submarine meadow. The turtle grass, Thalassia hemprichii (Fig. 4) is a frequent constituent, along with Halophila spp. Diplanthera uninervis, Cymodocea rotundata (Fig. 4) and Ruppia rostellata. Enhalus acorides (Fig. 4), which forms luxurious stands on tidal flats between mean low water and mean low water spring, is a prominent constituent of this community in other parts of Asia and is to be expected in the waters off Viet Nam. According to Miki (1934), the northern limit of the distribution of the Enhalus coincides with the 23° C February water temperature line. Since it is said to be absent from areas where many rivers empty in the ocean, it would be rare off the east coast of Viet Nam but might be expected off the west coast. The turtle grass, Thalassia, also seems to be bounded by the 21° C February isotherm. It is common in shallow sheltered bays, in pools in tidal flats of more open bays, and sometimes forms extensive submarine meadows with the other species mentioned above. Vertically it occurs from low water mark, where it is sometimes left dry by ebb tide, down to 5 meters, but it does not form meadows below 3.5 meters. Enhalus acoroides (Fig. 4), is the meadow-former below this depth. In monsoons the leaves may be washed up in huge piles which are a serious detriment to water navigation. They are probably just like those mixed masses of leaves which lined the eastern shore of the Chesapeake Bay after some strong blows in May of 1962. The plant seems to be incapable of vegetative reproduction by fragmentation. Halophila ovalis is a gregarious species found in sheltered sands and muds and on coral reefs to 5 m. deep. It extends far beyond tropical waters to the 10°C February water isotherm in Japan. Halophila beccarii (Fig. 4) is a rarer species more likely to be encountered in brackish waters or even in fish ponds. Numerous species of microscopic and macroscopic algae will be found in the sea meadows, several of them in the list of Zaneueld (1959). Apparently there are no free floating higher plants in the ocean. Algae may locally become detached and form great masses as those in the Sargasso Sea. Table 2 lists some of the marine algae of Vietnam.

These meadows can be dense enough to cause prop-fouling at low tide. They are probably closely analagous to submerged communities of pondweed (Potamogeton spp.), eel grass (Vallisnera) and sea lettuce (Enteromorpha) in the brackish waters of the Chesapeake Bay. Since these plants are attached they would increase in density as the tide receded.

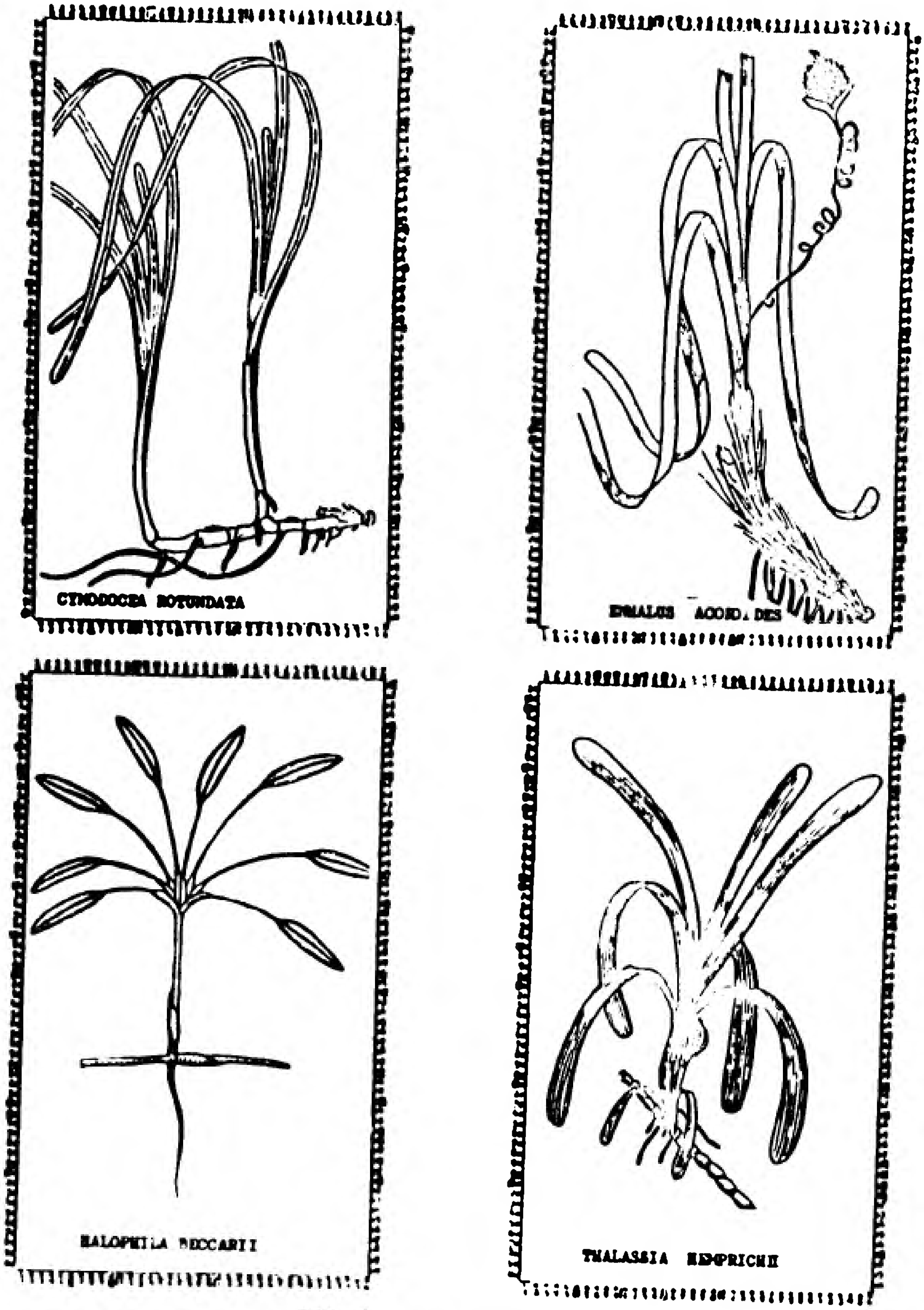


FIG. 4. SEA GRASSES

SCIENTIFIC NAME	VIETNAMESE NAME	FAMILY
Avrainvillea erecta	Rong Co	Green Algae
Bornetella oligospora	Rong Bornet	Green Algae
Brachytrichia maculans	Daon mao-dom	Blue Green Algae
Catenella nipae		Red Algae
Caulerpa peltata	Luc-quan long	Green Algae
Caulerpa racemosa	Luc-quan hot	Green Algae
Caulerpa serrata	Luc-quan quan	Green Algae
Caulerpa taxifolia	Rong Luc-quan la-dep	Green Algae
Ceratodictyon spongiosum	Rong da-giac	Red Algae
Chara		
Chnoospora minima		Brown Algae
Codium geppi	Rong nhung	Green Algae
Colpomenia sinuosa	Rong Bao-tu	Brown Algae
Dermonema frappieri	Rong hai-giac	Red Algae
Dictyota dichotoma	Rong vong-tao	Brown Algae
Ectocarpus breviarticulatus	Rong hai-tu	Brown Algae
Ectocarpus irregularis	Rong hai-tu	Brown Algae
Ectocarpus mitchellae	Rong hai-tu	Brown Algae
Enteromorpha clathrata	Thong tao min	Green Algae
Enteromorpha intestinalis	Truong tao to	Green Algae
Galaxaura		Red Algae
Gracilaria		Red Algae
Halimedia opuntia	Rong Xuong-song	Green Algae
Hildebrandia prototypus	Rong hien-dang	Red Algae
Hydroclathrus clathratus	Rong ruot-heo	Brown Algae
Hypnea	Rong vi-giac	Red Algae
Laurencia		Red Algae
Liagora	Rong bun	Red Algae
Lithophyllum	Thach diep	Red Algae
Neomeria annulata		Green Algae
Nitella		
Padina commersonii	Rong Doan-phiem	Brown Algae
Pocockiella variegata		Brown Algae
Porphyra crispata	Rong mut	Red Algae
Sargassum	Rong la-mo	Brown Algae
Turbinaria ornata		Brown Algae
Ulva lactuca	Rong xa-lach	Green Algae
Ulva reticulata		Green Algae
Valonia aegagropila	Dai-bao bui	Green Algae
Valonia utricularis	Dai-bao bau	Green Algae
Valonia ventricosa	Dao bao trung	Green Algae

TABLE 2: SOME VIETNAMESE ALGAE (Compiled from Cay-Co Mien Nam Viet Nam)

MANGROVES AND BACK MANGROVES

Vast expanses of both the east and west coasts of South Viet Nam are occupied by the foreboding mangrove community, a terrific barrier to boats at high tide and an equally difficult area for overland mobility at low tides. The gloomy mangroves are composed of very few species as contrasted with the inland forests which are usually composed of hundreds of species. There are more species however in Asiatic than American mangroves, and the trees tend to be slightly taller, especially in the Malasian Region. Between the Tropics of Cancer and Capricorn, mudflats inundated by saline waters and protected against high wind and wave actions, will often be occupied by mangroves. The mangrove community is likely to be encountered along streams but they never in nature extend beyond the reach of brackish water. According to Merrill (1945): "Because of the very extensive development of prop roots, these forests are particularly difficult to traverse, as one must step from slippery root to root, these often being set at dangerously sharp angles, so that each misstep plunges one into the deep soft mud...In such places where the mangrove forest is traversed by stream beds, deep penetration is possible by boat." Boatsmen would be well advised to know that the very nature of the streams along the lower reaches of the Mekong Delta are such that they might leave a boatsman stranded in some pool in an old oxbow or meander when low tide drains the water from all but the deeper streams.

To the true mangrove family (Rhizophoraceae) belong the genera Rhizophora, Bruguiera, Ceriops, Carallia and Kandelia.

Aegiceras corniculata	Cay Cat	Tree to 10 m.
Avicennia officinalis		Tree to 20 m. with pneumatophores
Bruguiera cylindrica	Vet	Buttressed tree to 23 m. with pneumatophores
Bruguiera gymnorrhiza	Vet re loi	Buttressed tree to 36 m. with pneumatophores
Bruguiera parviflora	Vet hoa nho	Buttressed tree to 24 m. with pneumatophores
Bruguiera sexangula	Vet den	Buttressed tree to 33 m. with pneumatophores
Carallia brachiata	Xang-ma	Stilted ant-tree to 50 m.
Carallia suffruticosa	Xang-ma	Shrub to 3 m.
Ceriops tagal	Cay Net	Stilted shrub or tree to 25 m.
Hibiscus tiliaceus	Tre lam cheo	Tree to 10 m.
Kandelia candel	Vet dia	Shrub to 7 m. with swollen base
Rhizophora apiculata	Duoc-doi	Stilted tree to 30 m.
Rhizophora mucronata	Duoc-nhon	Stilted tree to 30 m.
Sonneratia caseolaris	Ban trang	Tree to 20 m. with stout pneumatophores

TABLE 3: MANGROVE AND BACK MANGROVE SPECIES

Van Steenis (1958) has presented a thorough analysis of the ecology of the mangrove, a community that will be a problem to boats only at high tides. Rhizophora and Avicennia have analogous species in Darien, Panama where Grenke (1963) reported the following soil conditions. In a Rhizophora swamp the soils had rating cone indices of 3 at 0-6", 14 at 6-12" and 20 at 12-18". In the upper 6" he found 5.13 percent organic matter, 1400 lbs. Ca per acre, 250 lbs. K per acre, 200 lbs. P per acre, 16 lbs. N per acre and a pH of 6.4. At 6-12" he reports 5.7 percent organic matter, 7120 lbs. NaCl per acre, 700 lbs. Ca per acre, 350 lbs. K per acre, 200 lbs. P per acre, 28 lbs. N per acre and a pH of 6.7. In Darien, soils occupied by the black mangrove, Avicennia bicolor, were much more substantial, having rating cone indices of

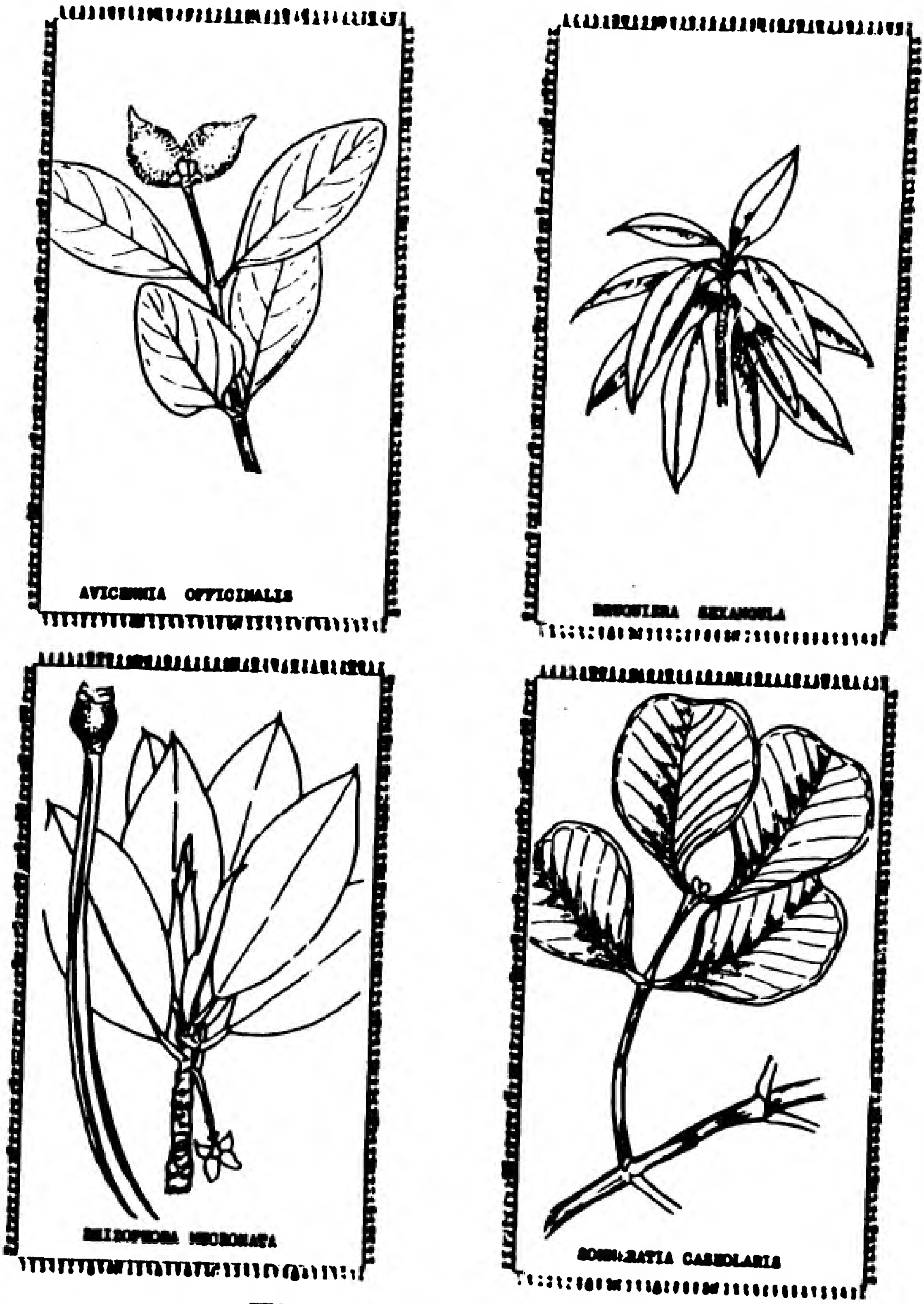


FIG. 5. MANGROVE SPECIES

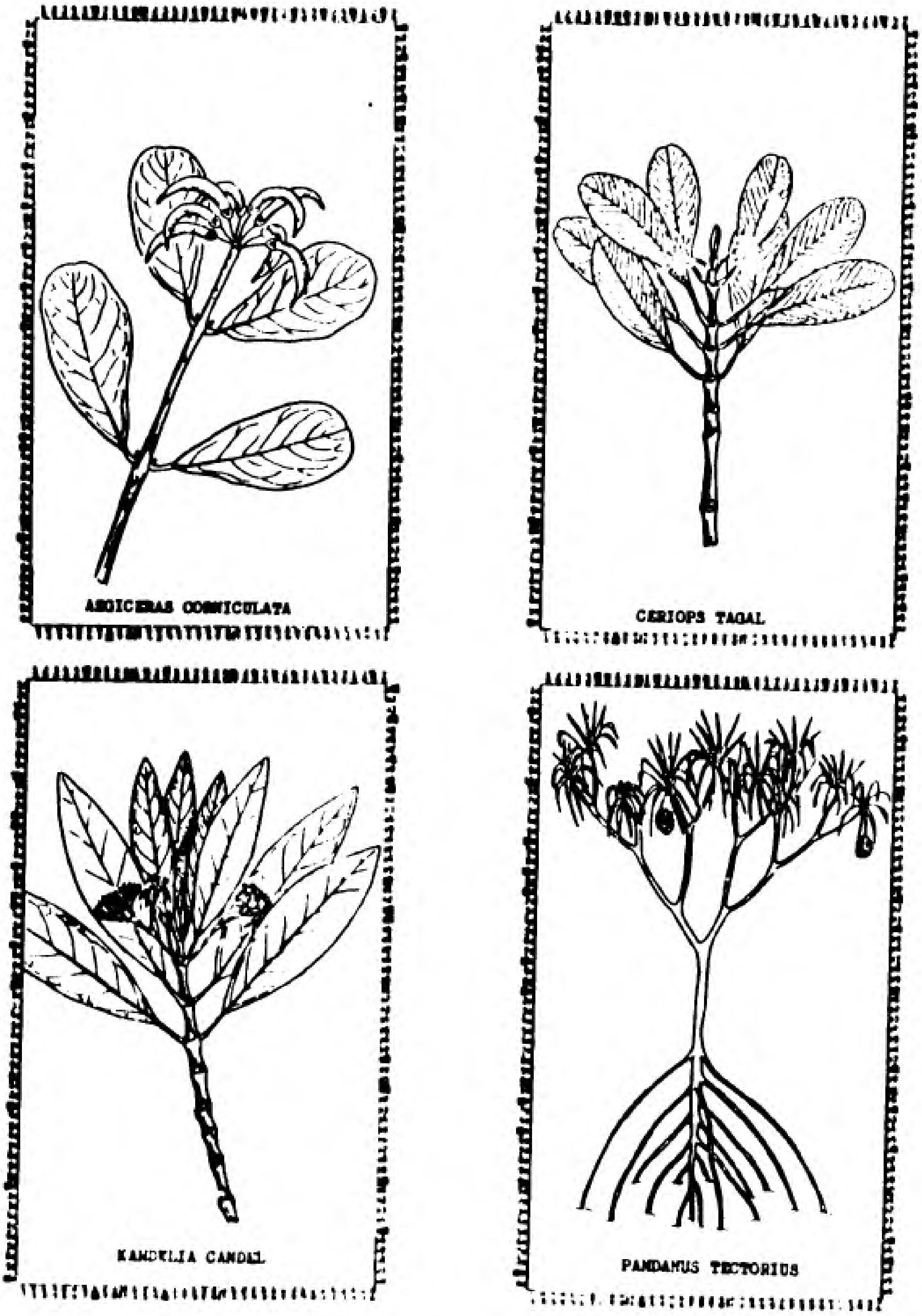


FIG. 6. BACK MANGROVE SPECIES

38 at 0-4", 61 at 4-12" and 67 at 12-18". In the top four inches, there was 5.13 percent organic matter, 11,484 lbs. NaCl per acre, 700 lbs. Ca per acre, 300 lbs. K per acre, 200 lbs. P per acre, 20 lbs. N per acre, and a pH of 6.8. At 4-12", there was 4.33 percent organic matter, 12,854 lbs. NaCl per acre, 700 lbs. Ca per acre, 350 lbs. K per acre, 200 lbs. P per acre, 28 lbs. N per acre and a pH of 6.8.

Mangroves of Asia are more rich in species than those of America, there being about 60 species in Malasian mangroves. Each seems to have its own niche so that the composition varies from place to place. According to Van Steenis (1958) "As...there is always an intricate mosaic surface relief with deeper and more shallow places, higher grounds are interspersed with creeks, and soil types vary from place to place from more sandy and firm to muddy and less firm or deep soft mud, the particular niches for the species are also available in a mosaic-like pattern. Moreover, rapid changes may occur in these coastal areas where creeks may be silted up, lagoons may be shut off from the open sea by bars, and deposits of silt may be replaced or covered by those of sand. The main factors responsible for the ecological preference of the mangrove species are the following three which may occur combined in a limited number of combinations:

1) Soil type, firm or soft, sandy or clayey in various proportions
2) Salinity and its variation both daily and to yearly average, roughly corresponding to the frequency, depth and duration of being flooded
3) Resistance to currents and surf of the mangrove species."

Rhizophora mucronata (Fig. 5) is generally typical of deep soft muds, while R. apiculata seems to be rather indifferent to soil type.

Bruguiera cylindrica was observed to die out over considerable areas in Malaya (Watson, 1928) due to suffocation caused by stiff clays.

The dense massive root systems of Nipa fruticans (Fig. 7) are better adapted to resist swift waters than most mangrove species. Nipa is more frequent on the outer bends of rivers than on the inner where current velocities and particles are smaller.

Watson (1928) classified mangroves on basis of what type tides would flood them as follows:

CLASS	INUNDATED BY:	HEIGHT ABOVE ADMIRALITY DATUM	TIMES FLOODED PER MONTH	SPECIES
1.	All high tides	-8 ft.	56-62	Rhizophora mucronata
2.	Medium High Tides	8-11 ft.	45-59	Avicennia officinalis Sonneratia caseolaris
3.	Normal Spring Tides	11-13 ft.	20-45	Rhizophora apiculata Ceriops tagal Bruguiera parviflora
4.	Spring High Tides	13-15 ft.		Bruguiera cylindrica Bruguiera sexangula
5.	Abnormal or Equinoctial Tides	15- feet		Bruguiera gymnorrhiza et al

TABLE 4: MANGROVE SPECIES ASSOCIATED WITH CERTAIN TIDE CONDITIONS

Salinity is higher in the dry season than in the wet, and is higher at low tides. Water samples at high tide in Java (de Haan, 1931) showed 10-30 o/oo NaCl in association with Rhizophora apiculata, R. mucronata, Bruguiera gymnorrhiza and B. parviflora, and 1-10 o/oo NaCl for Bruguiera sexangula (Fig. 5). Xylocarpus and Nipa have broad tolerance, with De Haan reporting 1-30 o/oo NaCl.

Avicennia (Fig. 5) and Sonneratia (Fig. 5) are frequently the pioneers with Rhizophora more frequent in protected estuaries not exposed to surf. In sluggish streams such as the Hooghly River near Calcutta, tidal brackishness and mangroves may extend upstream for 300 kilometers.

There is a better development of mangrove on the west coast than on the east coast (especially northeast) of Vietnam in accordance with the same principles that maintain in Malaya as reported by Watson (1928): "There is a distinct difference between the west and east coasts of Malaya, silting conditions being more favorable along the west coast. On the more exposed east coast wave action is more severe, particularly during the north-east monsoon, so that any fresh water brought down by the rivers is more speedily dispersed. Mangrove species are, therefore, unable to establish themselves along the beaches and are confined to the river mouths, whilst the sandy beaches themselves are flanked by a narrow belt of Casuarina equisetifolia which extends practically unbroken from Singapore northwards to far beyond the limits of Malayan territory.

"Where the flow of the river is sluggish the tendency is for banks of sand to be deposited at the mouth through the combined action of the currents and the north-east monsoon, the channel being forced thereby further and further south. The newly formed natural breakwater is speedily covered on its seaward edge with a dense growth of Casuarina, and subsequently on its protected side by mangrove forms brought down the river. The bank continues to advance in a southerly direction, until exceptional circumstances breach it and allow the water to escape by a new mouth. The old channel then rapidly silts up and soon becomes stocked with mangrove species which persist until a new bank is formed and again breached. The new channel is then in its turn converted into a mangrove swamp and the old one is invaded by inland forms.

"Nearly all of the east coast rivers show this tendency. It is most marked at Rumpin, Merchong, and Bebar, where successive folds in the ground running parallel to the coast and bearing a few straggling Casuarina on the ridges and decadent mangrove in the hollows, provide unmistakeable evidence of former banks and swamps. The last mentioned river demonstrates this process particularly clearly, the abnormal floods at the beginning of 1927 having broken through the Casuarina bank about 5 miles above the mouth of the previous channel, which is now beginning to silt up and be invaded by mangrove.

"On the west coast the mangrove is almost continuous from Kedah to Singapore. It varies in width from a few chains to a maximum of c. 19 km. at the mouth of the Larut River in the Matang District of Perak; but the mangroves follow the rivers much further inland, extending along the banks of the Perak River up to Telok Anson, at c. 50 km. from the sea.

"Changes of current and unusually heavy seas may sweep away the mud banks before the forest is fully formed, or even the mature forest may be eroded... disastrous floods on the east coast of the Malay Peninsula in the beginning of 1927 did considerable damage to the mangrove growing in the rivers, much of which was washed away or killed by excessive deposits of sand or silt. Large numbers of trees died as a result of prolonged inundation by practically fresh water, specially of Bruguiera gymnorrhiza. It is assumed to be a simple case of drowning; Nypa scarcely suffered from either immersion or silt." Seedlings of Rhizophora may occasionally be killed by excess of fresh water.

Mangroves may form sexually mature thickets in as little as three years, and are apt to form low thickets in sandy impoverished situations. Depauperate stands in Asia are often due to excessive cutting for charcoal manufacture. Low shrubs occurring in openings are Acanthus ilicifolius, Acrostichum aureum (Fig. 7), and Clerodendron inerme, and they are especially apt to occur in mudheaps provided by prawn, crabs and crabfish.

The legume genus Derris and the fern genus Stenochlaena are the only vines to occur in the mangrove proper, although farther back may be found various paludal species of the milkweed family. Derris uliginosa, one of the mangrove vines used to poison fish, may form pure stands to as much as 4-5 m. square. Ant-inhabited epiphytes are Hydnophytum and Myrmecodia.

The vegetation is often quite dense, and light intensity on the forest floor has been measured at 1-5 percent that of the open. In Mindoro, stands are reported with 500-1000 trees per hectare 10-30 cm. thick and 6-14 m. high. In a virgin mangrove forest in Mindanao one hectare had 149 trees over 25 cm. in diameter with a cubic content of 130 $m.^3$ per hectare. The woods of most maritime species in the mangrove are hard and rather highly flammable and their main use is for firewood, fuel and charcoal production. Perhaps some explanation for this is determined by their anatomy, i.e., heavy-barred scalariform perforations of the vessels, scalariform intervascular pitting, libriform fibers, scanty vasicentric parenchyma (ex. Kandelia, Fig. 6), fine celled rays, a high tannin content, and a high specific gravity Mangroves are often classed as xerophytes, a group usually considered as highly flammable, but since mangroves do not grow slowly they are not true xerophytes.

Water borne dispersal is called upon to explain the wide dispersal of many mangrove species. According to Guppy (1912) fruits a/o seedlings may drift for several months without losing their viability. In Perak mangroves, seeding of Rhizophora, Bruguiera and Ceriops spp. (Fig. 6) proceeds slowly with seeds from nearby trees and not from seeds that have been borne from afar, but seeds borne from afar may serve to introduce Avicennia and Sonneratia. Van Steenis points out another problem inherent in waterborne dispersal theories pertinent to mangrove. "No mangroves are known to occur native in the Hawaiian Islands, although they can grow there in certain localities, as has been shown by extensive planting experiments initiated by the Hawaiian Sugar Planter's Association in 1922." The temperature requirement prohibits species from migrating between oceans separated by N-S oriented continents, as Indo-Pacific species are lacking in the Atlantic and vice versa, while many of those of the Caribbean occur also in West Africa. East African mangroves show a closer floristic affinity with Indo-Malaysia.

Certain of the Vietnamese Mangrove Species are indicative of certain ecologic factors. Rhizophora apiculata forms colonies on deep soft estuarine muds flooded by normal high tides and seems to be intolerant of harder muds or sand admixtures. Trees are said to attain diameters of 30 cm. in about 35 years. The wood is very good for firewood because it has a high caloric value and splits easily. No species can survive complete daily inundation except perhaps gallery communities of Rhizophora mucronata which develops better on soils firmer and more rich in humus. Bark of Rhizophora may contain up to 30 percent tannin dry weight and contains high percentages of pentosans and furfurol, the ash largely lime and calcium carbonate. Bruguiera gymnorrhiza, one of the largest of the mangroves, is not to be found on the seacoast except following erosion, as it prefers drier better aerated soils, and is transitional to the inland swamps. According to De Haan it is found in areas flooded with water 10-30 o/oo NaCl up to 9 days a month where it may be often associated with the mangrove fern, Acrostichum aureum (Fig. 7).

Bruguiera parviflora is less exacting in its ecological demands than other species and forms pure stands under several conditions, usually on the inner belt of the mangrove submerged by normal spring tides. Bruguiera sexangula does not exhibit the gregarious nature of mangroves, and occurs isolated in areas flooded by spring high tides with salinities of 1-10 o/oo NaCl. This is the only species of the genus Bruguiera which under certain conditions develops stilt roots. Ceriops tagal (Fig. 6), a frequent bush-former with small stilt and aerial roots, occurs in well-drained soils reached only by the highest of tides and floods. Kandelia candel (Fig. 6), with swollen base, devoid of root modifications, is sporadic among inner mangroves but has been found as a pioneer on mud-shoals in the river mouths. Avicennia and Sonneratia are the most frequent pioneers on soft muddy young silts flooded by medium high tides and would appear to be more tolerant to the action of surf than Rhizophora. The mangrove palm, Nipa fruticans tolerates a wide range of salinity (1-30 o/oo NaCl), silting, and flooding but is often located on the outer banks of rivers where its extensive root system better adapts it to current resistance than other mangroves are adapted. Nipa is sometimes cultivated along the Mekong and Saigon rivers at the expense of other mangrove species which are used for firewood, fish traps, etc. The palms can be made to yield amazing quantities of sugar without killing them.

As has been pointed out, the mangroves would not grow in many waters except those that are navigable only at high tides, so the boatsmen should be concerned with mangroves only during high tides and floods. Density of the mangroves, especially the thicket-forming species, would as a rule physically preclude navigation, although navigable sloughs might traverse them. At high tides, the vertical often woody pneumatophores of species of Avicennia, Bruguiera, Sonneratia, etc., could easily contribute to pin-shearing. A rough analogue of this hazard would be submerged knee-roots to be found in cypress swamps of the southeastern United States. Stilt roots of adjacent trees of Rhizophora are often so intricately interwoven as to make the vegetation impenetrable by any normal means of transportation. Stilt roots an inch in diameter are hard and tenuous and can support the weight of a man.

PALM SWAMP

The Nipa Palm community is the Nipeto-Sonneratietum acidae of Van Cuong (1960) and is richer in species than the other aquatic and marsh communities of the Mekong Delta. In the Saigon Region Van Cuong breaks it down into the Cryptocoryne ciliata-Acanthus ebracteatus subassociation flooded by tides of 1.2-2.5 m. and the Annona reticulata-Flagellaria indica subassociation flooded only by tides of 2.5-3.8 m. Furthermore, the plants can be grouped into 4 lots as follows:

1. Species from the Mangroves: Acanthus ilicifolius, Bruguiera sexangula (Fig. 5), Carallia lucida, Derris uliginosa, Dolichenodrone rheedii, Flagellaria indica, Nipa fruticans (Fig. 7).

2. Species from the back mangrove (inner mangrove; l'Arriere-Mangrove): Acronychia pedunculata, Acrostichum aureum (Fig. 7), Canthium didymum, Cerbera manghas, Clerodendrum inerme, Ficus benjamina, Melaleuca leucadendron, Pandanus tectorius (Fig. 6), Stenochlaena palustris.

3. Fresh Water Gallery Species: Barringtonia acutangula, Gluta coarctata.

4. Rice Paddy Weeds: Cyperus procerus, Eleocharis equisetina, Phragmites karka.

The palm swamp often forms a transition to a terrestrial forest behind, closely or remotely, depending on the gradient. The terrestrial forest is largely composed of Bambusa sp., Carallia fascicularis, Cassia tora, Eugenia sp., Ficus sp., Glycosmis pentaphylla, Grewia paniculata, Litsea sebilifera, etc.

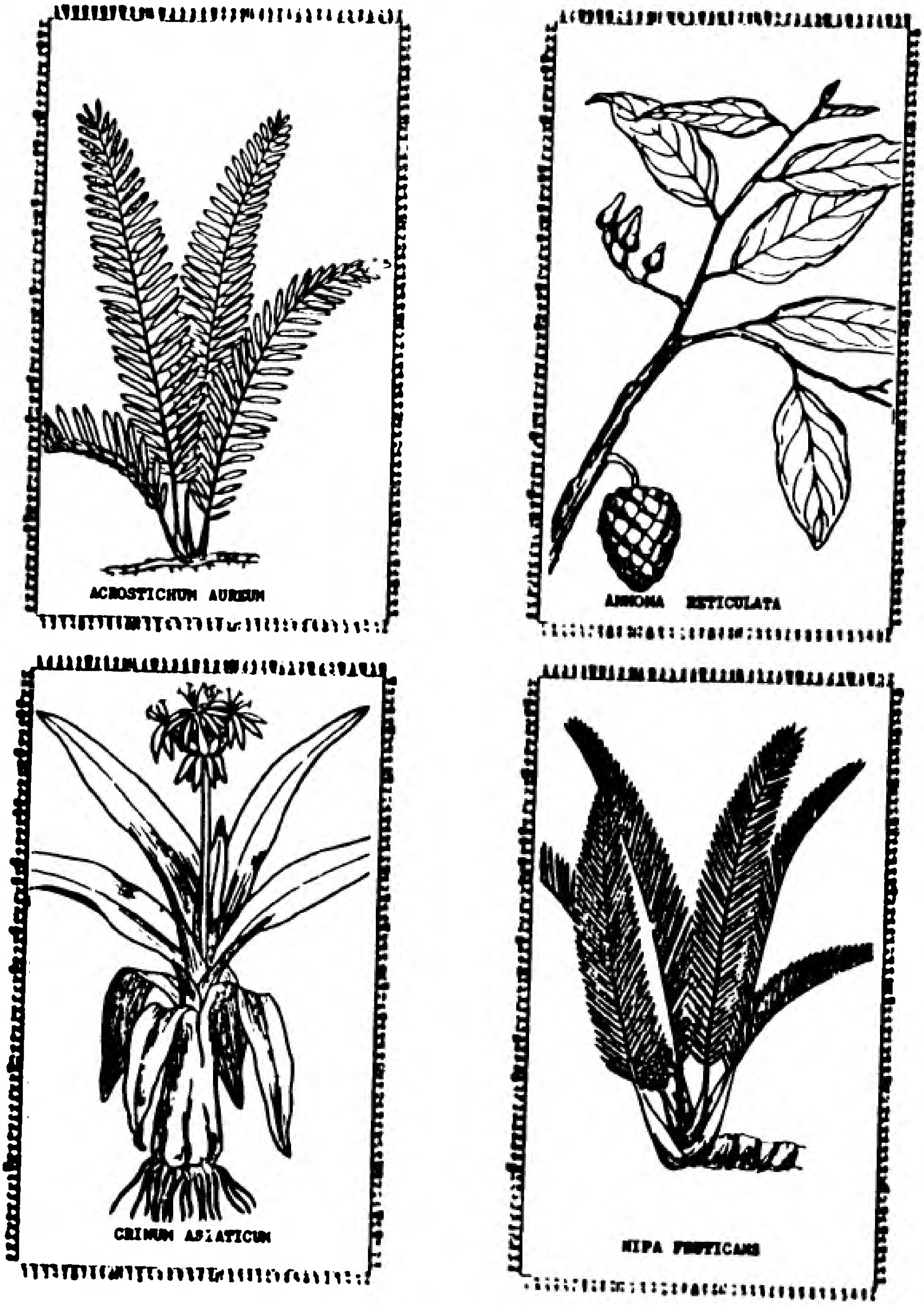
The ranges of various ecological measurements reported by Van Cuong for the Nipa Palm Community are as follows. Coarse sand = 3.05-7.72 percent; fine sand = 12.32-26.36 percent; silt = 28.72-32.00 percent; clay = 37.2-55.20 percent; pH = 3.8-5.0; P_2O_5 = 0.037-0.097 mgr./liter; K_2O = 0.100-0.214 mgr./liter; CaO = 0.118-0.318 mgr./liter; water soluble $Al_2(SO_4)3$ = traces-0.395; water soluble $FeSO_4$ = traces to 0.096.

On the Mekong River in the provinces of Travinh and Cantho, and in the Saigon and Vaico Rivers one can observe tidally inundated galleries composed of Acanthus ebracteatus, Crinum asiaticum, (Fig. 7), Cryptocoryne ciliata, Derris uliginosa, Nipa fruticans (Fig. 7), Sonneratia caseolaris (Fig. 5), and Typha angustifolia. Galleries such as this, flooded by tides of 1.2-2.5 m. are found also in the irrigation canal along National Route Number 1 from Pont de Binh Loi to Thu Duc and in ditches around Tan Thuan Dong, Thu Thiem and Giailnh. In riverine galleries, the Nipa is associated with the outer banks where currents are more pronounced, and Cryptocoryne ciliata and Crinum asiaticum associated with the slip-off slopes. If Crinum be uprooted and washed downstream it may form pure stands on fine muds not exposed to excessive salinity. Cryptocoryne can take moderate submergence and under such circumstances its leaves may reach 150 cm. long, much like those of Montrichardia in Panama and Peltandra in Walker's Lake. The cattail, Typha angustifolia (Fig.8), does not tend to form pure stands around Saigon, but it does form such in muddy soils flooded with fresh waters, such as the fresh water marsh bordering the Thuy Van Beach at Cap Saint-

Jacques. In Malaya it ranges from brackish marshes to mountainous bogs up to 1725 m.

According to Van Cuong, the peak of flowering in the palm swamp dominants is April to June; fruit maturation July to September and seed germination in October to November followed by seed dormancy.

Only under conditions of flooding and equinoctial tides will boatsmen be apt to penetrate stands of the Nipa palm. The boatsmen may use the Nipa palm as an indicator of stronger currents or deeper channels when it occurs on the outer banks of curves in the stream, the inner curve often being occupied by such species as Cryptocoryne ciliata and Crinum asiaticum. Cryptocoryne and Crinum occupy areas of heavy sedimentation with fine silts and clays, the Cryptocoryne apparently favored by very liquid soils and somewhat more salt-tolerant than the Crinum.



FIC . PALM SWAMP SPECIES

SPECIES	FREQUENCY PRESENCE		FREQ. PRES.
Utricularia flexuosa	100%; V	Enteromorpha cerulescens	30%; II
Ceratophyllum demersum	100%; V	Enhydrias angustifolia	30%; II
Hydrilla verticillata	80%; IV	Nitella sp.	20%; I
Naias kingii	60%; III	Chara sp.	20%; I
Spirogyra sp.	30%; II	Vallisneria spiralis L.	20%; I
	BLADDERWORT COMMUNITY		
Nymphaea stellata	80%; IV	Mimulus orbicularis	10%; I
Nymphaea lotus	30%; II	Ipomaea aquatica	60%; III
Jussiaea repens	20%; I	Neptunia prostrata	40%; II
	WATER LILY COMMUNITY		
Lemna polyrrhiza	50%; III	Pistia stratiotes	30%; II
Wolffia arrhiza	50%; III	Eichhornia crassipes	20%; I
Salvinia cucullata	30%; II	Azolla imbricata	10%; I
	DUCKWEED COMMUNITY		
Cyperus malaccensis	100%; V	Sphenoclea zeylanica	40%; II
Eleocharis equisetina	100%; V	Eclipta alba	30%; I
Ceratopteris thalictroides	100%; V	Monochoria vaginalis	30%; I
Cyperus procerus	80%; IV	Oldenlandia pinifolia	20%; I
Scirpus mucronatus	80%; IV	Aeschynomene indica	20%; I
Hygrophila angustifolia	80%; IV	Echinochloa crusgalli	20%; I
Sagittaria sagittifolia	80%; IV	Echinochloa colona	20%; I
Fimbristylis miliacea	60%; III	Echinochloa stagnina	20%; I
Cyperus haspan	60%; III	Panicum repens	20%; I
Scirpus grossus	60%; III	Brachiaria distachya	20%; I
Fuirena umbellata	60%; III	Eichhornia crassipes	20%; I
Cyperus difformis	40%; II	Eriocaulon gracile	20%; I
Eriocaulon caribea	40%; II	Digitaria marginata	10%; I
Cyperus polystachyus	40%; II	Ipomaea aquatica	10%; I
Xyris indica	40%; II	Leersia hexandra	10%; I
Limnocharis flava	40%; II	Setaria barbata	10%; I
Monochoria hastata	40%; II	Polytrias amaurea	10%; I
Acrostichum aureum	40%; II	Paspalum orbiculare	10%; I
Rynchospora aurea	40%; II		
	SEDGE COMMUNITY		
Nipa fruticans	100%; V	Eleocharis equisetina	50%; III
Sonneratia acida	100%; V	Scirpus mucronatus	40%; II
Derris uliginosa	80%; IV	Fuirena umbellata	40%; II
Acrostichum aureum	50%; III	Rhynchospora aurea	40%; II
Annona reticulata	20%; I	Sphenoclea zeylanica	20%; I
Sarcolobus globosus	20%; I	Limnocharis flava	20%; I
Cryptocoryne ciliata	100%; V	Aeschynomene indica	I
Acanthus ebracteatus	100%; V	Echinochloa crusgalli	I
Typha angustifolia	40%; II	Echinochloa colona	I
Crinum asiaticum	40%; II	Echinochloa stagnina	I
Alocasia esculenta	30%; II	Brachiaria distachya	I
Lasia spinosa	30%; II	Phragmites karka	I
Cyperus malaccensis	80%; IV	Commelina nudiflora	20%; I
Ceratopteris thalictroides	80%; IV	Eriocaulon caribea	10%; I
Sagittaria sagittaefolia	70%; IV		
	PALM SWAMP		

TABLE [illegible]: AQUATIC PLANT COMMUNITIES AROUND SAIGON

	NIPA FRUTICANS	SONNERATIA ACIDA	BRUGUIERA SEXANGULA	ANNONA RETICULATA	CARALLIA LUCIDA	BARRINGTONIA ACUTANGULA	PANDANUS TECTORIUS
pH	3.4-5.0	3.0-7.7	3.4-4.6	3.4-5.0	5.0	3.4-5.0	4.6-5.0
Coarse Sand %	3.0-7.7	12.3-26.4	6.5-7.7	3.0-7.7	6.5	3.0-7.7	3.2-7.7
Fine Sand	12.3-26.4	12.3-26.4	12.3-26.4	12.3-26.4	12.8	12.3-26.4	12.8-26.4
Silt	28.0-32.0	28.0-32.0	28.0-32.0	28.0-32.0	28.7	28.0-32.0	28.7
Clay	37.2-55.2	37.2-55.2	37.2-49.2	37.2-55.2	55.2	37.2-55.2	37.2-55.2
P_2O_5 mgr/1	0.02-0.10	0.02-0.10	0.02-0.09	0.02-0.10	0.10	0.02-0.10	0.09-0.10
K_2O	0.10-0.21	0.10-0.21	0.10-0.20	0.10-0.21	0.21	0.10-0.21	0.20-0.21
CaO	0.12-0.32	0.12-0.32	0.23-0.32	0.12-0.32	0.12	0.12-0.32	0.12-0.32
$Al_2(SO_4)_3$	-0.40	-0.40	-0.40	-0.40	trace	-0.40	-0.02
$FeSO_4$	-0.10	-0.10	-0.10	-0.10	trace	-0.10	-0.05

TABLE 6: SOIL ANALYSES ASSOCIATED WITH SWAMP TREES

SEDGE MARSH

Helophytic species of the sedge community of the Saigon area (Cypereto-Eleocharetum equisetinae of Van Cuong) are listed in Table 5. The dominant members of the community are tall sedges and grasses emerging from the marshes. The sedge community is found both in marshes or terrain covered with 5-8 decimeters of water at high tide. Soil analyses associated with some of the involved species are shown in Table 7. Rice paddies or rizieres are found in similar circumstances and they are often formed by the laborious clearing of the sedge community. Lateritic soils (alunees) with poor drainage or stagnant water are often occupied by pure stands of Eleocharis equisetina, as are certain fallow rice fields, abandoned fish ponds and stagnant marshes. The plant, which rarely attains more than 8 decimeters in height, is very similar to the cultivated Eleocharis dulcis (Fig. 9) and both seem favored by bright sunlight, and, the former at least, tolerates prolonged desiccation by the sun. It forms conspicuous associations on the Plaine des Joncs. Like Eleocharis, Cyperus malaccensis occurs in clay-silts flooded daily by the tide, and may form extensive pure stands to 2 m. high. Reproducing both vegetatively and sexually, the Cyperus is quick to form pure stands which are only with difficulty cleared for rice culture. Cyperus malaccensis indicates the best potential soils for rice culture. Ceratopteris thalictroides, the water fern (Fig. 8) occupies much the same ecological niche. Other species occasionally forming pure stands under similar conditions are Limnocharis flava (Fig. 8), Monochoria hastata (Fig. 13), Scirpus grossus and S. mucronatus. Cyperus procerus, with smaller flowers than Cyperus malaccensis, often takes over mud-choked rice fields.

Seeds of the sedge community usually germinate after a period of dormancy in April to June with the commencement of the rainy season and the plants reach sexual maturity and flower in August to September, the seeds usually maturing by November.

Some of the lateritic marshes are so heavily endowed with sulphates of iron and aluminum as to be toxic to rice. Properly managed these can however be utilized for sugar cane and pineapple.

Only in times of flood or equinoctial tide will boats be liable to traverse this community. Sedges are often very tough and wiry and could pose a serious fouling factor. Good analogues can probably be found in the bullrush (Juncus) and sedge (Scirpus, Cyperus) species of the salt marshes of the Southeastern United States. These species will probably respond favorably to flame treatment.

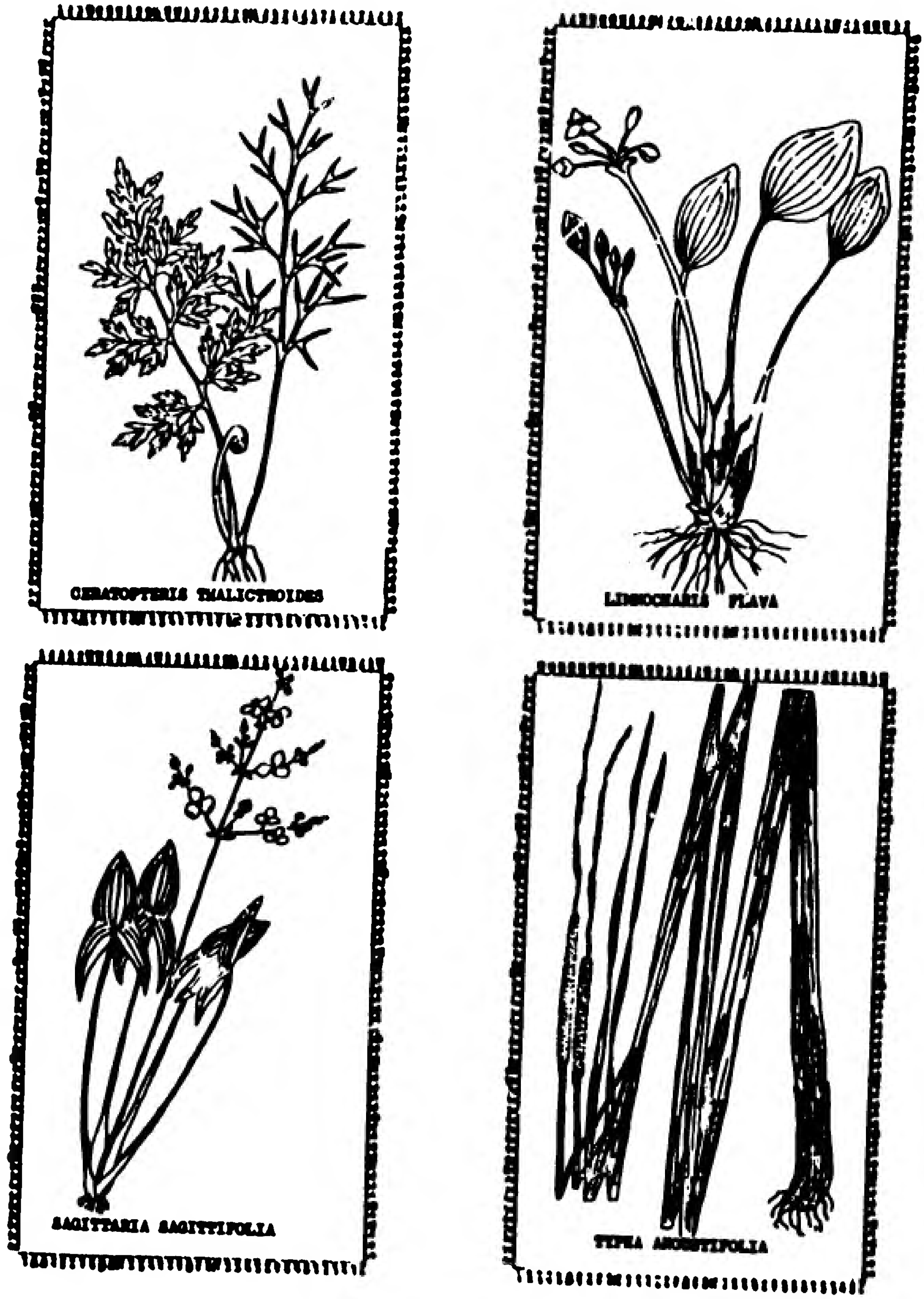


FIG. 8. SEDGE MARSH SPECIES

	CERATOPTERIS THALICTROIDES	SAGITTARIA SAGITTIFOLIA	LIMNOCHARIS FLAVA	MONOCHORIA HASTATA	ACROSTICHUM AUREUM	SPHENOCLEA ZEYLANICA	ECHINOCHLOA COLONA
pH	3.9-5.2	3.9-5.2	4.5-5.2	4.7-5.2	3.4-5.2	4.5-5.1	4.6-5.2
Coarse Sand %	0.6-53.4	0.9-53.4	0.6-2.4	0.9-53.4	0.6-4.6	1.6-4.6	0.6-4.6
Fine Sand	8.7-31.7	8.7-31.7	11.6-31.2	8.7-24.7	11.6-31.2	23.6-31.2	11.6-23.6
Silt	12.7-34.7	12.7-32.7	32.7-34.7	12.7-28.7	30.7-34.7	28.7-32.7	30.7-34.7
Clay	25.2-55.2	25.2-45.0	35.2-53.0	25.2-53.0	35.2-53.0	35.2-45.0	41.0-53.0
Total Nitrogen mgr./liter	0.16-0.43	0.16-0.43	0.23-0.39	0.16-0.37	0.23-0.43	0.37-0.39	0.23-0.37
P_2C_5	0.01-0.04	0.01-0.03	0.02-0.03	0.01-0.04	0.01-0.03	0.01-0.04	0.01-0.02
K_2O	0.09-0.21	0.09-0.20	0.14-0.16	0.09-0.21	0.14-0.20	0.15-0.21	0.14-0.17
CaC	0.17-0.33	0.18-0.29	0.17-0.29	0.18-0.33	0.17-0.29	0.26-0.33	0.17-0.26
$Al_2(SO_4)_3$	0.03-0.18	0.07-0.18	0.13-0.18	0.03-0.10	0.10-0.17	0.09-0.18	0.13-0.16
$FeSO_4$	0.010.13	0.01-0.13	0.01-0.02	0.01-0.05	0.01-0.13	0.01-0.13	0.10-0.13

TABLE 7: SOIL ANALYSES ASSOCIATED WITH MARSH PLANTS (2 Dm. Deep)
(After Van Cuong, 1960)

RICE PADDIES

Rice occupies the same ecological niche as the sedge community and in the thickly populated Mekong Delta probably occupies a large percentage of the area. Tropical oriental agriculture is centered about rice which is usually grown as an aquatic, in some places even being harvested from boats. Farmers over the course of centuries have developed or selected aquatic side crops, e.g., Acorus calamus, the sweet flag; Eleocharis dulcis, the water chestnut (Fig. 9); Ipomaea aquatica, an aquatic morning glory (Fig. 12); Monochoria spp. (Fig. 13); Nelumbium spp., the water lotuses (Fig. 12); Sagittaria sagittifolia, the Chinese Arrowhead (Fig. 8), and Trapa bicornis, the buffalo nut (Fig. 13). Hydrolea zeylanica (Fig. 9), young leafy tops of which serve as a potherb, is so abundant in some Malayan rice fields as to color them blue in December and January when it is in flower.

Rice areas are derived by draining and irrigating and diking sedge marshes. Delta plains, with their level land and copious water, afford the best sites for rice culture and consequently almost three-fourths of the delta plains are devoted to rice culture. According to the University of Michigan report, "...on the Mekong, deeply flooded paddies produce 'floating' rice, which is planted in dry land, then deeply flooded and harvested from boats. (See Fig. 10). Broad paddy areas such as those of the deltas of the Irrawaddy, Chao Phraya, the Mekong, and the Red Rivers, represent a unique environment for military operations. Some of the elements of this environment are:

1. During flooded periods or in wet places there would be great difficulties in deployment, lateral movements, circumvention of roadblocks, etc.

2. Area would be open to constant air observation because of the absence of concealing cover.

3. Operations would be completely dependent on roads.

4. Any off-road operations would be carried out with hand weapons and the advantage of mechanization and armor would be negligible.

5. Extensive paddy areas are densely populated."

We might deduce that in the fallow season the rice paddies will bear a limited amount of overland traffic. Crowley (1963) reports that they make good landing pads for helicopters. Unquestionably he is referring to the dry season described rather vividly by Croft (1963), "The rice paddies have hardened to a brick-like consistency in the searing sunshine. Only a few months ago, it seemed that the rain saturated Delta of South Viet Nam would forever be a vast morass. But the monsoon has long ago subsided. The dry season is upon us. It's hot - and getting hotter." It is doubtful that the "floating" rice paddies would make good pads during the flooded wet season, when they are trafficable to boats. During the flooded season about Saigon, the following species may occur as weeds:

Submerged Species: Ceratophyllum demersum, Enhydrias angustifolia, Utricularia flexuosa.

Floating Species: Jussiaea repens, Lemna polyrrhiza, Mimulus orbicularis, Nymphaea stellata, Wolffia arrhiza.

Amphibious Species: Eleocharis equisetina, Limnocharis flava (Fig. 8), Monochoria hastata (Fig. 13), and Monochoria vaginalis.

All except the amphibious species are eliminated when the fields are drained of all their water around December or January. Monochoria vaginalis dies out when desiccated. According to Backer in Van Steenis (1958) flowers of one variety of Monochoria hastata close at 14.30 hours. In some rice fields after the harvest in January, the ground becomes so dry that it cracks. In such terrain in March and April stunted specimens of the following weeds appear: Acrostichum aureum, Cyperus haspan, Cyperus malaccensis, Eleocharis equisetina, Eriocaulon caribea, Fimbristylis miliacea, Rhynchospora aurea, Scirpus mucronatus, Sphaeranthus africanus, Sphoeromariscus albescens. Such fields are rather susceptible to fires and may be burned intentionally. With the first rains, they proliferate with vegetative growth and seed germination.

In wetter paddies regularly flooded after the harvest, mixed or pure stands of Cyperus malaccensis, Eleocharis equisetina, a/o Scirpus mucronata may attain coverages of 90-95 percent by April. Such terrain may also be occupied by populations of Panicum repens and Fimbristylis miliacea. These would probably not be so easy to burn as the preceding.

Irrigation canals, some navigable by rather large water craft, if not properly attended, quickly become choked with Ceratopteris thalictroides (Fig. 8), Echinochloa crusgalli, Eleocharis equisetina, Nymphaea stellata and Panicum repens.

The dikes bounding the paddies are often clothed with Fimbristylis miliacea, Heliotropium indicum, and Panicum repens.

A range of soil analyses associated with some of the weeds found in rice paddies is shown in Tables 7 and 8. A rice calendar and a map showing distributions of different systems of rice culture are included in Figs. 10 and 11.

Since most of the fields are drained after the harvest in December or January, to be reflooded with the advent of the rainy season in April or May, the rice paddies would normally be trafficable to boats during the wet season. Since weeds such as Cyperus, Eleocharis and Scirpus may attain 90-95 percent coverage as soon as April in flooded paddies, and since rice itself forms a rather dense community, they would be difficult on motor boats because of the fouling and blockage factors of the emergents and submergents and it is assumed that fertilized fields would have rather heavy blooms of duckweed types which could contribute to clogging of the cooling systems. Nonetheless the harvesting in several places on the Mekong Delta is done from boats, probably hand-powered. Where irrigation water is available during the dry season, a second flooded crop may be grown (See Fig. 10).

Many of the larger irrigation canals are trafficable all year round, but weeds would gradually encroach on them from the sides. Many of the smaller canals are tidal and would be navigable at high tides, but they would probably be subject to more rapid weed encroachment. Much of the Mekong Delta is a reticulum of ditches, canals, meanders, streams and flooded rice paddies separated by narrow dikes which are relatively low. Light craft, such as some of those tested at Walker's Lake could easily be carried over the narrow dikes from one paddy or drainage system to another.

Stands of wild rice, which occurs spontaneously and was recently planted at Walker's Lake, would probably simulate paddy conditions closely.

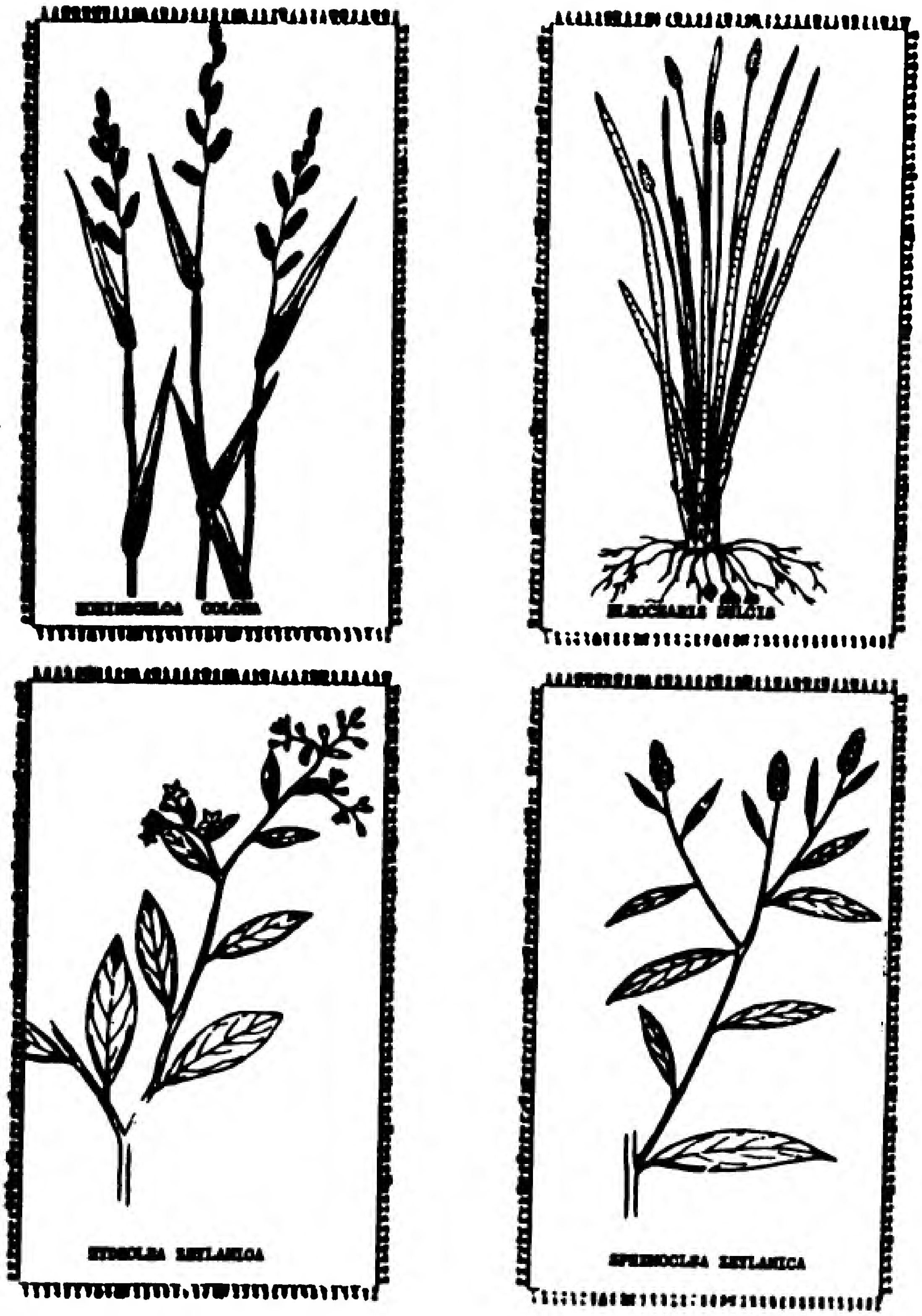
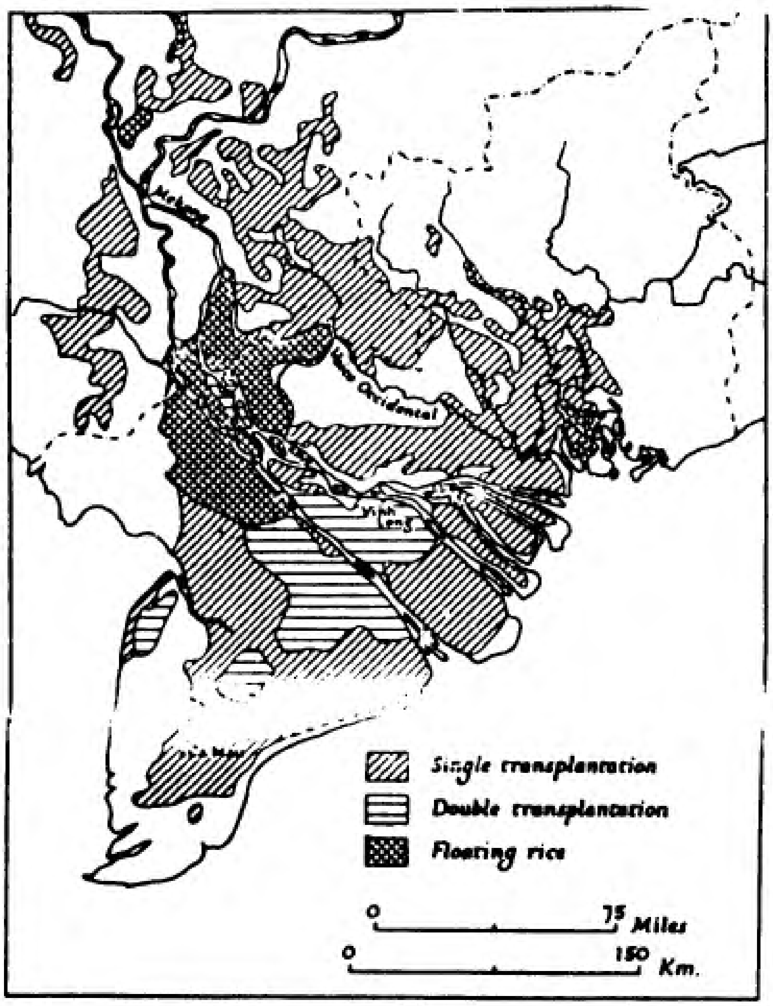


FIG. 9. RICE PADDY SPECIES



Source: Exposition Coloniale Internationale, Paris, 1931. *Riziculture en Indochine*, following p. 44 (Hanoi, 1931).

FIG. 10. TYPES OF RICE CULTIVATION IN INDO CHINA

FALLOW FIELDS WELL IRRIGATED

Appearance of the *Cyperus malaccensis-Eleocharis equisetina* Association. *Cyperus malaccensis* dominant, often in pure stand

FALLOW FIELDS WITH STAGNANT WATER

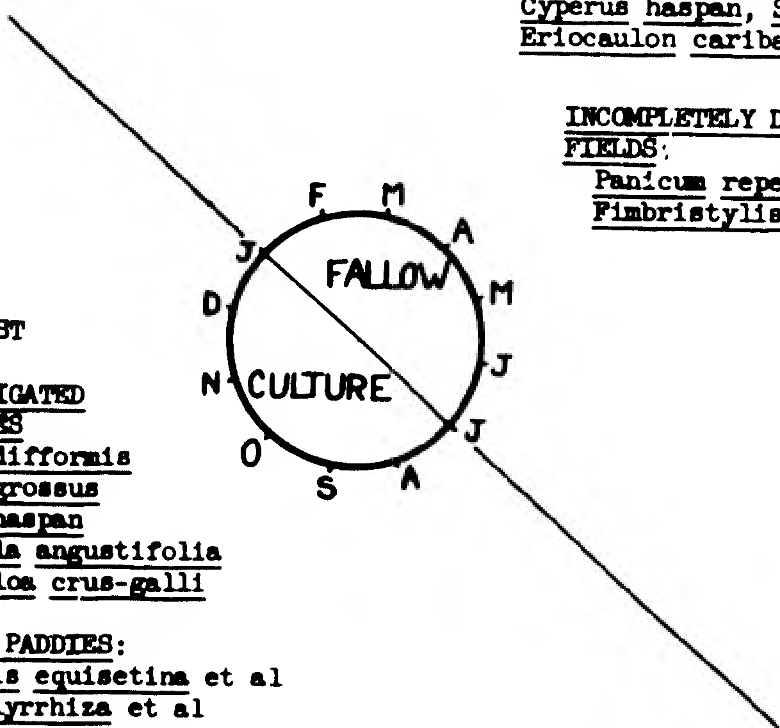
Cyperus malaccensis-Eleocharis equisetina Association. *Eleocharis* dominant, often in pure stand

DESICCATED FALLOW FIELDS:

Sphoeomariscus albescens, *Rhynchospora aurea*, *Acrostichum aureum*, *Cyperus haspan*, *Scirpus mucronatus*, *Eriocaulon caribaea*

INCOMPLETELY DESICCATED FALLOW FIELDS:

Panicum repens
Fimbristylis miliacea



HARVEST

WELL IRRIGATED PADDIES

Scirpus difformis
Scirpus grossus
Scirpus haspan
Hygrophila angustifolia
Echinochloa crus-galli

STAGNANT PADDIES:

Eleocharis equisetina et al
Lemna polyrrhiza et al
Nymphaea stellata et al
Utricularia flexuosa et al

TRANSPLANTING

CUTTING FOLLOWED BY BURNING

FIG. 11. RICE CULTIVATION CALENDAR FOR THE SAIGON AREA
(After Van Cuong)

WATER LILY COMMUNITY

Ponds too deep for rice and sluggish streams will often be choked with three communities; the water lily community, composed largely of species which root in the bottom but have floating leaves (anchored floaters), the duckweed community, composed of free floating large leaved (macrophyllous) and minute leaved (microphyllous) species, and the bladderwort community, composed of attached and non-attached species which grow submerged.

Fish ponds have multiplied around Saigon with the arrival of North Vietnamese refugees. The ponds mostly vary from 100 meters square to two hectares (ca. 5 acres) and were intentionally dug for fish culture. One was excavated in February of 1957 at Binh Quoi. The first plants to become established in this pond were the water lily, Nymphaea (Fig. 12), and the bladderwort, Utricularia flexuosa. Two months later appeared the water fern, Ceratopteris thalictroides (Fig. 8), Enhydrias angustifolia, Hydrilla verticillata (Fig. 14) and Vallisneria spiralis (Fig. 14). In December of 1959, the center of the pond was occupied by Nymphaea, Hydrilla and Utricularia; the borders were occupied by Ceratopteris, Fuirena umbellata and Eleocharis equisetina. On dikes and mounds bordering such ponds could be found Annona reticulata (Fig. 7), Breynia rhamnoides, Flagellaria indica, Glochidion littorale and Pandanus tectorius (Fig. 6). Van Cuong observed similar zonation in ponds at My An, Thu Thiem, Chang Hung and Tan Thuan Dong. An analysis of the waters of the lake at Binh Quoi is presented in Table 8.

Anchored floaters tend to reach their vegetative peaks in October and December about Saigon. Nymphaea stellata is very common about Saigon and tends to grow better in very acid waters. Another species of water lily, Nymphaea lotus, is typical of stations where the water is at least a meter deep, but it is rare about Saigon, since the leaf stalks are avidly sought as vegetables. Ipomaea aquatica (Fig.12) Neptunia prostrata (Fig. 12) and Nelumbium nelumbo (Fig. 12) are cultivated as food sources but may occur spontaneously. In Walker's Lake, Virginia, the swamp loosestrife Decodon verticillata, when it forms flotation stems, is a good analogue of Ipomaea and Neptunia. The Ipomaea (Fig. 12) is killed by excess brackishness.

Anchored floaters tend to have long, tenuous, slippery, rope-like leaf stalks and flower stalks which tend to wrap around propellor shafts ultimately causing fouling. Nymphaea and Nelumbo are usually good indicators that the water is normally quite deep enough to support water traffic of the boats of the size tested at Walker's Lake. Sharper propellors would suffer less fouling in waters heavily infested with water lilies.

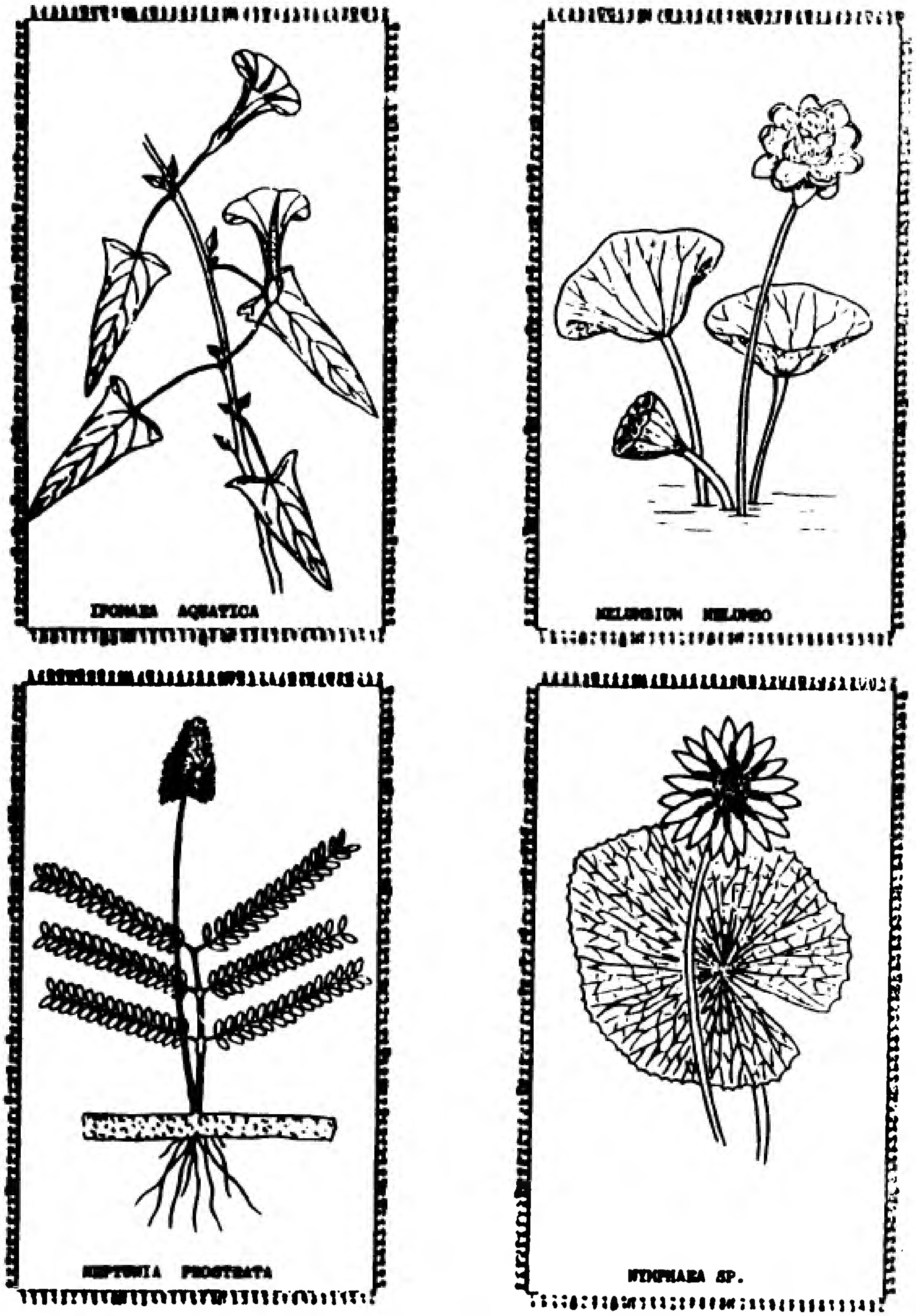


FIG. 12. SPECIES OF THE WATER LILY COMMUNITY

	EICHORNIA CRASSIPES	IPOMAEA AQUATICA	NAIAS KINGII	NEPTUNIA PROSTRATA	NYMPHAEA STELLATA	PISTIA STRATIOTES	VALLISNERIA SPIRALIS
pH	4.0-6.4	4.0-7.4	2.8-6.6	4.0-7.4	2.8-6.8	4.5-6.6	2.8-5.5
Dissolved CO_2 mgr./liter[2]	6.1	7.3-45.2	6.1-44.4	7.3-44.0	61-334.7	41.5-44.0	334.7
Dissolved O_2	7.0	0.9-4.8	0.9-7.0	0.9-4.6	1.5-7.0	0 9-4.8	6.3
Cl^-	213.5	140-4178	213-3385	140-3385	140-4178	31‾2-3385	274.5
NO_3	---	0.2-0.7	0.2-0.7	0.0-0.7	0.2-0.7	0.2-0.7	0.7
Carbonates	27.5	36.7-97.9	27.5-73.4	36.7-73.4	0.0-97.9	42.8-73.4	---
SO_4^{--}	32.4	79.1-523.7	32.4-451.3	79.1-451.3	32.4-753.6	413-415	753.6
PO_4	0.8	0.1-2.0	0.1-0.8	0.8	0.1-2.0	0.1-0.8	0.5
Na	122.3	104-2274	122-1844	104-1844	104-2274	1709-1844	242
K	4.5	61.3-80.4	4.5-68.1	-68.1	-80.4	61.3-68.1	13
NH_4	---	0.0-1.6	0.0-1.6	0.0-1.6	0.0-1.1	0.0-1.6	---
Ca	7.9	11.9-98.8	7.9-78.1	11.9-78.1	7.9-98.8	73-78	37
Mg	15.8	14.3-287.7	15.8-241.0	14.3-241.0	14.3-287.7	227-241	33
Fe^{++}	0.3	0.0-7.0	0.3-2.7	0.0-2.1	0.0-71.4	2.1-2.7	71
Al^{+++}	0.3	0.0-3.7	0.3-2.7	0.0-2.1	71.4	2.1-2.7	71.4

TABLE 8: WATER ANALYSES ASSOCIATED WITH AQUATIC PLANTS

DATE	Nov. 11	Jan. 9	Mar. 2	Apr. 3	Jun. 11
pH	6.6	6.2	6.6	6.3	5.1
Dissolved O_2 mg./1	6.0	5.0	4.9	5.1	3.7
Dissolved CO_2 mg./1	9.8	14.7	28.1	44.0	28.1
Chlorides	13.7	350.8	2653.5	7104.0	5381.0
Nitrite	0.2	trace	trace	trace	trace
Nitrate	2.3	1.2	6.9	0.9	trace
Carbonates	21.4	18.3	42.8	39.8	30.6
Sulfate	10.7	57.2	363.4	475.6	350.3
Silicate	11.4	12.7	10.2	25.4	27.9
Phosphate	0.8	1.1	2.0	0.8	1.1
Sodium	12.2	199.1	1451.8	1915.4	1381.0
Potassium	trace	8.2	53.7	66.8	52.0
Ammonium	trace	trace	0.0	trace	trace
Calcium	5.5	11.1	60.6	71.7	55.4
Magnesium	5.2	27.2	189.1	245.4	184.9
Iron	2.3	1.1	0.7	0.8	0.7
Aluminum	0.0	0.0	2.1	10.0	10.6

TABLE 9: ANALYSES OF THE SAIGON RIVER AT BINH QUOI

DUCKWEED COMMUNITY

Free floating plants, occurring in the same waters with the previous community, belong to the duckweed community termed Lemneto-Wolffietum arrhizae by Van Cuong. The constituent species, varying from minute duckweed to large water hyacinths which may block the waterways of Florida, are listed in Table 5. The water hyacinth Eichornia (Fig. 13) does not form floating islands near Saigon but is much more prevalent in the fresh water marshes, such as at Thuduc. This serious water weed, which has been eradicated by hand, by chemicals and by burning in India (Sen; 1961), prospers also in the brackish waters of Vinh-long, Travinh and Gocong. Around Saigon, the duckweeds Lemna polyrrhiza and Wolffia arrhiza, are more conspicuous from June to December, and they are not infrequent as scums in rice fields, especially well-fertilized paddies. Both the water lettuce Pistia (Fig. 12), and the water hyacinth Eichornia (Fig. 12), can form dense floating masses. Superficially the water hyacinth resembles the buffalo burr, Trapa bicornis, (Fig. 12) which also has swollen bladder-like leaf bases which enable them to float. At first these bladdery leaves are attached to the bottom by numerous stems clothed with lace-like modifications. Floating parts may persist even after having become detached. Although Monochoria (Fig. 12) is by rights a marsh plant or weed in rice paddies, it very frequently forms floating islands in southeast Asia and is probably a worse traffic hazard than any of the above.

The minute duckweeds constitute a minor problem to boats. They sometimes form solid green scums coating ponds and sluggish streams. Under such circumstances they may rarely cause clogging of the cooling system. Of course when they form solid stands they may mask more serious obstacles below them. One of the floating ferns, Salvinia auriculata, is estimated to have spread over 22,000 acres of Ceylon rice fields and over 2,000 acres of waterways in twelve years (Williams, 1956). Heavy winds characteristic of the monsoon climate may pile up the duckweeds and even the larger water hyacinth and water lettuce on the leeward sides of bodies of water to form dense floating islands difficult if not impossible to traverse in boats. However, the piling up of water on the leeward side of bodies of water may quickly be reversed when oscillation begins, so that the novice traversing such areas may quickly find himself high and dry in a bunch of water weeds entangled in some of the drier marsh emergents. It is under such circumstances that the free floaters may be decimated by burning. (Sen, 1961)

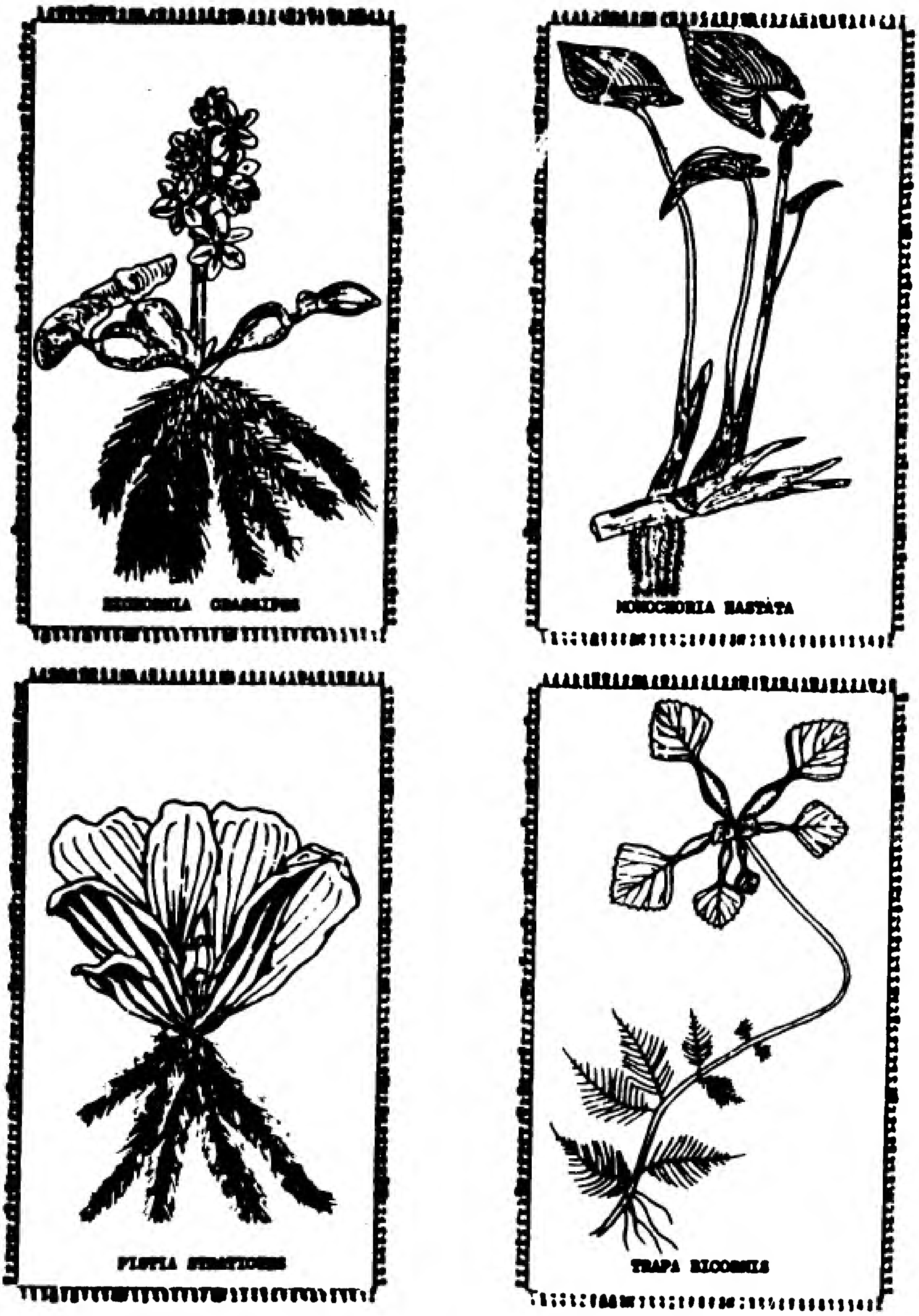


FIG. 13. SPECIES OF THE DUCKWEED COMMUNITY

BLADDERWORT COMMUNITY

The community of submerged water plants in the acid waters around Saigon is termed the Utricularietum flexuosae by Van Cuong. A l[illegible] of the species encountered is presented in Table 5. The bladderwort Ut[illegible]laria flexuosa pr spers best at a pH of around 7, but has a wide biological amplitude and will live in waters of pH down to 2.8. This is one of the first species to appear in newly excavated ponds and the last to disappear in those canals which are dry in the dry season. The coontail Ceratophyllum demersum (Fig. 14) has stems that are very elongate so that when the water leve[illegible] is high they are not too far below the surface. It establishes itself at moderate depths but is often broken off by currents and then continues to survive at the mercy of the currents, often dieing back at the base and growing at the tip. It shows its maximum vegetative activity in the months when the water is non-saline and by vigorous vegetative reproduction may tend to form dense pure stands to the elimination of other species. The leaves may be encrusted with lime or with mud, and it is said that they aid sedimentation. Naias kingii is quite common but never so gregarious as the preceeding. It grows better around Bung (Phu Cuong), perhaps due to the absence of brackish water, and its stems may reach a meter long there. Hydrilla verticillata (Fig. 14) occurs from sea level to 2,000 m. and goes down in water to 7 m. deep but in such deep waters it does not reach the surface. In agitated waters also, the plant remains closely confined to the bottom. In muddy water the leaves contribute to sedimentation. Vegetative and sexual reproduction make this a gregarious species found in most fresh water situations and occasionally in tidal waters as about Saigon, where its vitality is considerably reduced. In Viet Nam it has been observed in the basin of Cam ly (Dalat). Among the anchored submergents are the algae Chara and Nitella and the higher plants Vallisneria spiralis (Fig. 14) and Enhydrias angustifolia. Enhydrias, which attains better development in fresh water, occurs also in brackish waters, and it forms dense stands in the River Parfums de Hue. All these submerged species are rather tender plants with poorly developed root systems and so they are characteristic of waters with little or no currents. The eel grass, Vallisneria, with tapelike leaves to 1 m. long occurs in sluggish low-elevation waters and rarely grows much deeper than 2 m. It occasionally forms dense stands.

TRAFFICABILITY: Since the submergent plants of the Saigon River are rather weak, they should not greatly hinder water traffic. However, when waters are low, the same amount of vegetable matter would be present until some died out, so colonies would be much denser per unit volume of water at low water, and would be more likely to cause minor foulage. Although the species are quite different, the reaction of the fresh water submerged plants with boats should be about the same as that of the sea meadows, except there might be a greater tendency for calcification hardening the species of the sea meadows and their associated algae.

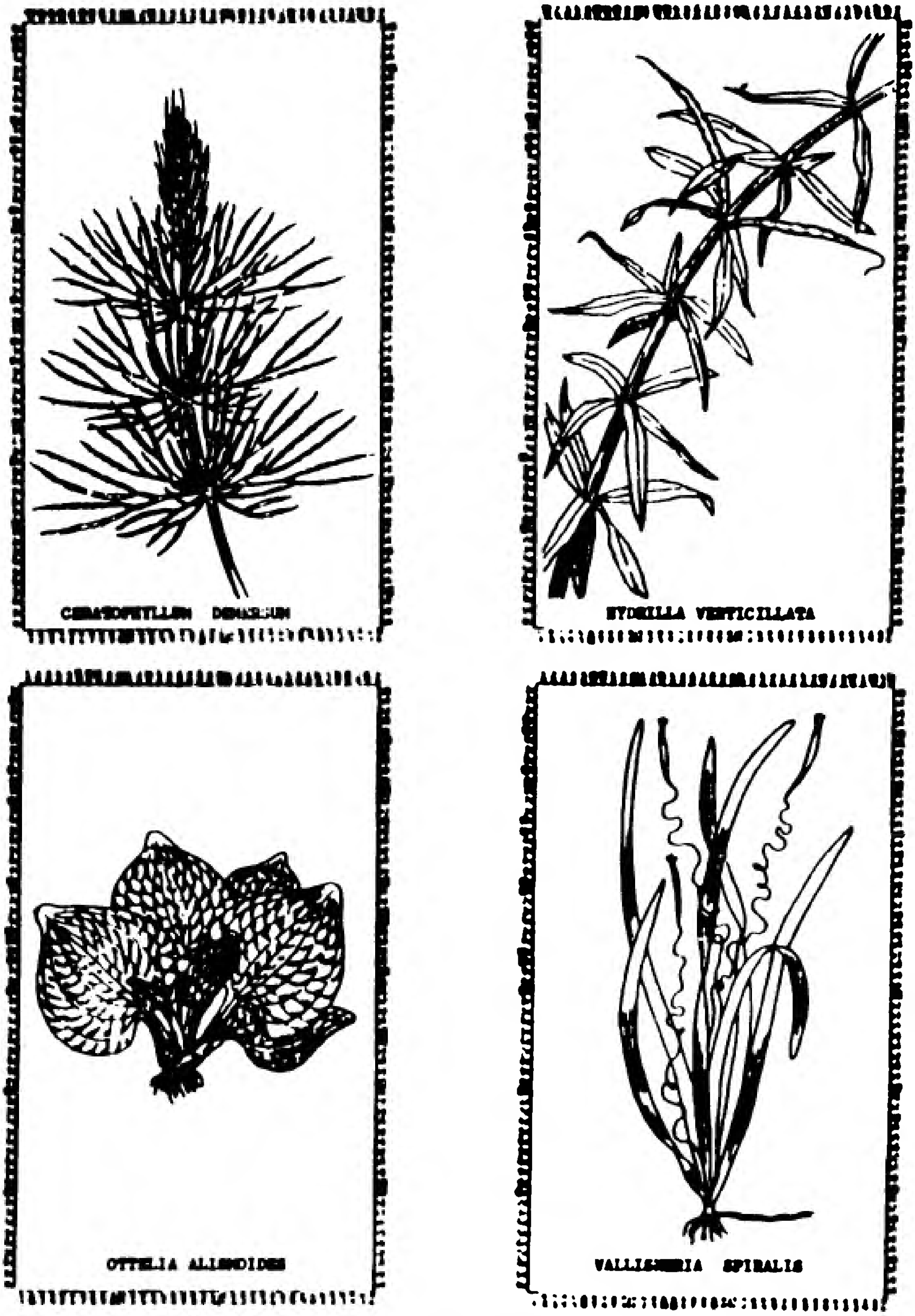


FIG. 14. SPECIES OF THE BLADDERWORT COMMUNITY

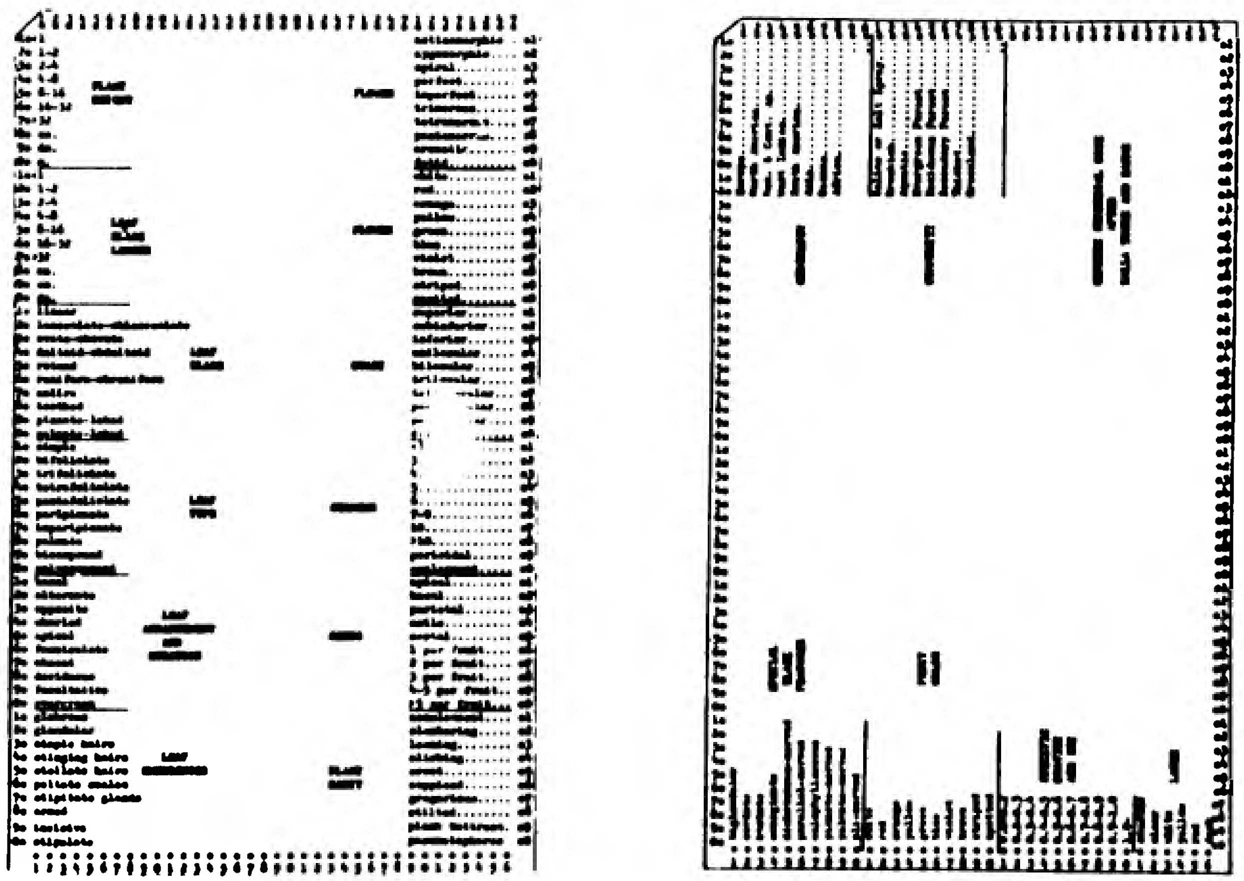


FIG. 15. CODING FOR FACSIMILE PUNCHCARDS

SPECIES	VIETNAMESE NAME	pH RANGE	PROJECTED HAZARD	HABIT AND HABITAT
Acanthus ebracteatus	O-ro	3.4-5.0	Fouling	Brackish Emergent
Acrostichum aureum	Rang lam choi	3.4-5.2	Blockage	Salt Marsh Fern
Aeschynomene indica		4.7	Blockage	Marsh Legume
Alocasia esculenta	Khoai	4.5-4.6	Blockage	Marsh Emergent
Annona reticulata	Binh bat	3.4-5.0	Blockage	Marsh Tree (Custard Apple)
Avicennia officinalis			Pin Shear	Mangrove with Pneumatophores
Azolla imbricata	Beo giau		Clogging	Floating Fern
Bergea ammanoides			Fouling	Emergent Herb
Brachiaria distachya	Co mat	3.9-5.2	Blockage	Emergent Grass
Bruguiera sexangula	Vet den		Blockage	Brackish Mangrove
Callitriche stagnalis	---		Fouling	Emergent Herb
Centella asiatica	Rau ma		Fouling	Emergent Pennywort
Ceratophyllum demersum	Co kim-ngu	2.8-6.0	Fouling	Submerged Coontail
Ceratopteris thalictroides	Rang gac-nai	3.9-5.2	Fouling	Brackish Fern
Chara	---	5.0	Fouling	Submerged Alga
Commelina nudiflora	Rau trai	4.6	Fouling	Emergent Herb
Crinum asiaticum	Chuoi nuoc	3.5-4.7	Blockage	Mudflat Emergent
Cryptocoryne ciliata	Mai dam	3.4-5.0	Blockage	Mudflat Emergent
Cyperus difformis	---	4.8-5.1	Blockage	Marsh Emergent
Cyperus haspan	---	4.7-5.2	Blockage	Marsh Emergent
Cyperus malaccensis	Lac lam-chieu	3.5-5.2	Blockage	Marsh Emergent
Cyperus polystachyus	---	5.1-5.2	Blockage	Marsh Emergent
Cyperus procerus	---	4.7-5.2	Blockage	Marsh or Paddy Emergent
Derris uliginosa	Coc ken	3.5-4.7	Blockage	Mangrove Vine
Digitaria marginata	---	5.2	Blockage	Marsh Emergent
Diplanthera uninervis	Co song-hung		Fouling	Saline Submergent
Echinochloa colona	---	4.6-5.2	Blockage	Emergent Grass
Echinochloa crusgalli	---	4.7-5.2	Blockage	Emergent Grass
Eclipta alba	Co muc	4.7-5.2	Blockage	Emergent Herb
Eichornia crassipes	Luc binh	4.0-6.4	Fouling	Floating Herb
Eleocharis equisetina	Nang	4.6-5.2	Blockage	Bauxite Swamp Emergent
Enhydra fluctuans	Rau Ngo		Fouling	Marsh Emergent

TABLE 10: VIETNAMESE AQUATIC SPECIES

Enhydrias angustifolia	Rau rong	4.0-6.0	Fouling	Submergent
Enteromorpha cerulescens	Truong tao	2.8-5.0	Fouling	Submerged Alga
Eriocaulon caribea	Dui trong	4.5-5.2	Blockage	Salt Marsh Emergent
Eriocaulon gracile	Co dui trong yeu	5.2	Blockage	Marsh Emergent
Fimbristylis miliacea		4.7-5.2	Blockage	Emergent Sedge
Flagellaria indica	Day may-nuoc	3.4-5.0	Blockage	Marsh Vine
Fuirena umbellata	---	3.9-5.2	Blockage	Emergent Sedge
Halophila ovalis	Ai-diem	---	Fouling	Brackish Free-floater
Hydrilla verticillata				
Hydrolea zeylanica			Fouling	Emergent Herb
Hydrophila angustifolia	Dinh-lich	5.1	Blockage	Emergent Herb
Ipomaea aquatica	Rau muong	4.0-7.4	Fouling	Floating Vine
Jussiaea repens	Rau dua trau	5.5-6.0	Fouling	Floating Herb
Lasia spinosa	---	3.4-4.6	Blockage	Emergent Aroid
Leersia hexandra	---	4.7	Fouling	Floating or Emergent Grass
Lemna minor	Beo-cam mot re	---	Clogging	Floating Duckweed
Lemna polyrrhiza	Beo-danh trong	4.5-6.0	Clogging	Floating Duckweed
Lemna trisulca	Beo cam ba canh	---	Clogging	Floating Duckweed
Limnanthemum hydrophyllum	Thuy nu nho	---	Fouling	Floating Herb
Limnanthemum indicum	Thuy nu an	---	Fouling	Floating Herb
Limnocharis flava	Ne thao vang	4.5-5.2	Fouling	Emergent Herb
Mimulus orbicularis		5.5	Fouling	Emergent Herb
Monochoria hastata	Rau mac	4.7-5.2	Blockage	Emergent Herb
Monochoria vaginalis	Rau mac la thon	5.1-5.2	Blockage	Emergent Herb
Myriophyllum spicatum	Co bach diep	---	Fouling	Submerged Coontail
Naias kingii	Co rung	2.8-6.6	Fouling	Submerged "Grass"
Nelumbium nelumbo	Sen		Fouling	Floating Lily
Neptunia prostrata	Rau nguc	4.0-7.4	Fouling	Floating Vine
Nipa fruticans	Dua nuoc	3.4-4.7	Blockage	Mangrove Palm
Nitella	---	---	Fouling	Submerged Alga
Nymphaea lotus	Sun do	4.5-5.5	Fouling	Floating Lily
Nymphaea stellata	Sun co	2.8-6.8	Fouling	Floating Lily

Oldenlandia pinifolia	An-dien la thong	4.8-5.1	Blockage	Emergent Herb
Oryza sativa (Rice)		4.4-6.0	Blockage	Emergent Grass
Ottelia japonica		---	Fouling	Floating Herb or Emergent
Panicum repens	Co cua-ga	4.7-5.2	Fouling	Emergent Grass
Paspalum orbiculare	---	4.9	Blockage	Emergent Grass
Phragmites karki	Say		Blockage	Emergent Herb
Philydrum lanuginosum	Bon bon		Blockage	Emergent Herb
Pistia stratiotes	Beo cai	4.5-6.6	Fouling	Floating Herb
Polytrias amaurea		5.1	Blockage	Emergent Grass
Potamogeton sp.			Fouling	Floating "Lily"
Rhizophora mucronata	Duoc nhon		Blockage	Stilted Mangrove
Rhynchospora aurea		3.9-4.6	Blockage	Brackish Marsh Sedge
Ruppia rostellata			Fouling	Submerged "Grass"
Sagittaria sagittifolia	Co Tu Co	3.9-5.2	Blockage	Emergent
Salvinia cucullata	Thu nhi		Clogging	Floating "Duckweed"
Sarcolobus globosus	Day Cam	3.4-5.0	Blockage	Emergent Vine
Scirpus grossus	Lac voi	4.7-5.2	Blockage	Salt Marsh Sedge
Scirpus mucronatus		3.5-5.2	Blockage	Salt Marsh Sedge
Sonneratia caseolaris	Ban trang	3.4-5.0	Blockage Pin-Shear	Mangrove with Pencil Roots
Sphenoclea zeylanica	Xa-bong	4.5-5.1	Blockage	Emergent Herb
Spirogyra sp.			Clogging	Floating Alga
Susum anthelminticum			Fouling	Emergent Herb or Floater
Terniola carinata			None	Encrusting "Moss"
Trapa bicornis	Au		Fouling	Floating
Typha angustata	Thuy huong	4.5-4.6	Blockage	Emergent Cattail
Utricularia flexuosa	Nha can	2.8-6.0	Fouling	Submerged Bladderwort
Vallisneria spiralis	Toc tien nuoc	2.8-5.5	Fouling	Submerged Eelgrass
Wolfia arrhiza	Beo Phan	2.8-5.5	Clogging	Floating Duckweed
Xyris indica		4.8-5.2	Fouling	Marsh Emergent

VIETNAM AND VIRGINIA

It is difficult to assess the analogies between vegetation of areas not studied in the field, but in Table 11 is a crude bibliographic method for assessing the analogy between the aquatic flora of Viet Nam, Panama, Florida and Virginia. Most of the tests of water boats were conducted in Virginia, which although showing the lowest analogy rating, probably is an adequately close analogue for comparison.

In Table 11 are included a list of some of the more prominent aquatic plants of Vietnam. Assessment of analogy is based on the not always valid assumption that related species and genera have taxonomic features correlated with features that would be of significance to hydromobility. The indices of analogy are set up as follows. If the area has the same species, it gets a rating of 5. If it has a closely related aquatic species in the same genus, it receives a rating of 4. If it has another member of the genus neither closely related nor aquatic, it receives an index of 3. If related aquatic genera are found the index rating is 2. If related non-aquatic genera are found the rating is 1. If no member of the same family occurs, the rating is 0. This analogy is derived strictly on the basis of specific composition. Ecologists are agreed that there are tendencies in the plant kingdom to develop the same physiognomy (external aspect) in areas quite distant from each other but with the same environmental circumscription.

There are pictures of the aquatic vegetation in Van Cuong's work that could be reasonably imitated by photographs of certain areas in Walker's Lake, Virginia. Pictures could be taken in areas of tidewater Virginia which would be very difficult to separate from Van Cuong's first four figures. Of course Virginia lacks palms and mangroves but does have many of the same species that occur in the waters around Saigon. Another problem arises in making analogies. We may state that a given species occurs in Walker's Lake and in the rice paddies of Saigon, e.g., Typha angustifolia, but it is well known that a given species will behave differently in different climates. Species that are evergreen in Florida may be deciduous in Virginia (e.g., Quercus spp.). Certain species may have uncut leaves when growing in a terrestrial environment and very finely divided leaves in water. Species that depend largely on seeds for reproduction in the north may depend largely on vegetative reproduction in the south. The water hyacinth, a terrible water problem in America and in Asia, has never been observed to set seed in Malaya, but it is far from scarce there.

It should be remembered that Table 11 contains some salt water species and some fresh water species which would never be found growing together and hence could not be duplicated in any one place in nature. Table 12 contains a list of the important water weeds of Walker's Lake, Virginia, with their reactions on boat traffic and projected analogues from the slightly brackish waters around Saigon. Reactions of the boats with the projected analogues should be rather similar. For example, the arrow arum (Peltandra) and the Pickerelweed (Pontederia), both lacking in Vietnamese waters, are closely simulated by Monochoria (Fig. 13). Usually all three of these plants grow in swampy soils, even in the shade of the forests, but it is not uncommon for any of them to form floating islands. They share another interesting feature. When they form these islands, portions of the colony tend to die out, but fibrous veins in the leaf stalks persist and may be extremely tough. Such fibers frequently wound around the propellors of boats being tested in Walker's Lake and caused stoppage. It should be understood that these fibers are non-living and that they would therefore not be considerably altered by killing the living plants in the floating islands.

VIETNAMESE SPECIES	PANAMA	FLORIDA	VIRGINIA	VIRGINIA ANALOGUE
Acrostichum aureum	5	5	2	Pteridium
Annona reticulata	5	3	3	Annona
Avicennia officinalis	4	4	0	Taxodium
Azolla imbricata	4	4	4	Azolla
Bruguiera sexangula	2	2	0	Taxodium
Ceratophyllum demersum	5	5	5	Ceratophyllum
Ceratopteris thalictroides	5	5	3	Pteridium
Crinum asiaticum	3	3	3	Crinum
Cryptocoryne ciliata	2	2	2	Peltandra
Cyperus malaccensis	4	4	4	Cyperus
Echinochloa colona	5	5	5	Echinochloa
Eichornia crassipes	5	5	5	Eichornia
Eleocharis equisetina	4	4	4	Eleocharis
Flagellaria indica	0	0	0	Smilax ?
Halophila ovalis	4	4	0	Ruppia
Hydrilla verticillata	2	2	2	Ammania ?
Ipomaea aquatica	3	3	3	Decodon?
Jussiaea repens	4	4	4	Jussiaea
Lemna minor	5	5	5	Lemna
Limnocharis flava	5	5	2	Heteranthera
Monochoria hastata	2	2	2	Peltandra
Myriophyllum spicatum	5	5	5	Myriophyllum
Naias kingii	4	4	4	Naias
Nelumbium nelumbo	4	4	4	Nelumbium
Neptunia prostrata	5	5	2	Decodon
Nipa fruticans	2	1	0	None
Nymphaea stellata	4	4	4	Nymphaea
Oryza sativa	5	5	5?	Zizania
Pistia stratiotes	5	5	2	Eichornia
Rhizophora mucronata	4	4	0	None
Sagittaria sagittifolia	4	4	4	Sagittaria
Sonneratia caseolaris	0	0	0	Taxodium
Sphenoclea zeylanica	0	0	0	Ludwigia
Trapa bicornis	0	0	4	Trapa
Typha angustifolia	5	5	5	Typha
Utricularia flexuosa	4	4	4	Utricularia
Vallisneria spiralis	5?	5	5	Vallisneria
Wolffia arrhiza	4?	4?	4	Wolffia
TOTAL RATING	138	135	111	

TABLE 11. ANALOGY RATING OF VIETNAMESE AQUATICS

0 = No Relation
1 = Related Non-aquatic Genus
2 = Related Aquatic Genus
3 = Remote Non-aquatic Species
4 = Related Aquatic Species
5 = Same Species

PLANT	MASSING (Bailing on Forward Lower Unit)	PROP FOULING (Binding)	WRAPPING (Lower Unit)	BODILY RESISTANCE AND GROUNDING	CIRCULATION SYSTEM CLOGGING	PROJECTED SAIGON ANALOGUE
Arrow Arum (Peltandra)		x	x	x		Monochoria
Spatterdock (Nuphar)	h			m		Nelumbium
Waterweed (Elodea)	x		s			Hydrilla
Watershield (Brasena)	m	s	s			Nymphaea
Bladderwort (Utricularia)	s	s	s			Utricularia
Pickerelweed (Pontederia)	m	x	s			Monochoria
Loosestrife (Decodon)		x	x	h		Ipomaea
Duckweeds (Lemna etc.)					s	Lemna etc.
Milfoil (Myriophyllum)	h	n.	m	m		Myriophyllum
Coontail (Ceratophyllum)	s	s	s			Ceratophyllum

TABLE 12: BOAT REACTIONS WITH WATERWEEDS PROMINENT IN WALKER'S LAKE, VIRGINIA

(Modified from data assembled by CWO Tyndall)

x - severe; h - heavy; m - moderate; s - slight

ELIMINATION OF WATER WEEDS

By Harry Mussell

The object of this section is to consider various methods of controlling the aquatic vegetation, with particular reference to efficient clearing of the waterways for mechanized boat travel. With this approach in mind, the only control and suppression methods that will be considered here are those that are relatively easy to apply, take effect within one to three weeks, and have relatively long lasting effects.

The term aquatic vegetation is one of broad application, generally applied to any vegetation, regardless of taxonomic classification, found growing in, on, under, and in some cases near a natural body of water. It stands to reason that in dealing with such a broad group of plants, the methods of control, suppression, and eradication will vary greatly. Some of the species can be controlled only by physical means, others respond in varying degrees to one or many of the various chemical controls available. Biological control of aquatic vegetation (see e.g. Shell; 1962) will not be considered here because it is generally slow in effect.

By definition, a plant species or group of plants will be considered controlled when it is no longer an actual or potential impediment to boat traffic. In some cases, the plants will not be killed, but the part or parts that impede water traffic will be eliminated, and their redevelopment will be inhibited.

It must be emphasized here that control of aquatic vegetation, with reference to water traffic is a new concept, and the work done on tropical hydrophytes is scarce and in some cases not dependable. The considerations of this paper therefore must necessarily be a subjective projection of the known results of control methods.

MECHANICAL CONTROL

In many cases, mechanical or physical control, especially applied in conjunction with a chemical program, is the quickest and most efficient method of clearing waterways. The following are the commonly accepted methods of mechanically clearing waterways, and their relative usefulness in the control of tropical hydrophytes.

HAND CUTTING AND RAKING: For the purposes defined in this paper, these methods are too inefficient and impractical to be considered. However, Vietnamese are known to hand clear sedge communities for rice culture.

MECHANICAL WEEDERS AND CUTTERS: Many types of mechanical weeders and cutters have been developed (See e.g. Schuberth; 1956), and these are very effective for clearing large bodies of water of emergent species such as *Cyperus*, and some species of deep rooted surface floating plants also respond favorably to these treatments. In running water, the cut parts of the plants may float away, and deteriorate rapidly, presenting no further menace to navigation. Plants cut in still water, especially stagnant water, must be raked or removed in some other way from the water. In still water the cut parts tend to gather in clumps that will foul propellors, and generally impede traffic. Under normal still water conditions, these plants cannot be counted on to decompose rapidly, their decomposition being directly proportional to the dissolved oxygen content of the water (Mussell, unpublished).

Bullrushes, cattails, and certain other emergent types are particularly vulnerable to cutting immediately after their flower peak, and before the fruits have set (e.g. August near Saigon). Cutting at this time is recommended, not only because of the vulnerability of the stalks, but by cutting before the fruits and seeds ripen, one exerts a certain amount of suppression on the regeneration of the species.

<u>DRAGGING</u>: This method is particularly effective for removal of deeply rooted floaters and emergent reeds. It is especially well adapted to canals and rivers, where the turbulence caused by the chain will be washed away, carrying with it any broken plant parts not held by the chain. The usual method is to drag a heavy chain through the area to be cleared by means of a tractor on either bank. As with cutting, the weeds are more susceptible to dragging when they are fully developed. Chancellor (1958) seems to think that dragging with grapnels and prongs is more effective, but it is the opinion of the author that a combined chain dragging and chemical treatment will be more effective for weeds that tend to resprout from rootstocks.

<u>DREDGING</u>: This method is a very efficient way to control and remove floating and submerged species that are anchored on the bottom. Unfortunately, it is a very expensive and extensive operation, and it is the feeling of this writer that it would not be justified in the Mekong Delta region, except for overgrown canals that bear heavy traffic.

<u>BURNING</u>: It is obvious that this method can usually be used only for emergent species. However, when used in combination with a chemical program, it is one of the most efficient ways of dealing with emergents. Many authors recommend the use of a flame thrower for this job. Sen (1961) discusses eradication of water hyacinth by burning it after it had been left high and dry by receding waters. Use of flame throwers might be worthwhile to prevent seeding of floating species unable to reproduce vegetatively.

Control of aquatic weeds by temporary drainage of the canals and subsequent drying out by sunshine is practiced on a minor scale in southern France. "The burning or flaming of emergent vegetation is becoming more important as an additional measure following the use of chemicals (dalapon paraquat) to remove large amounts of dead organic material." (Weed Res. 3: 69. 1963)

CHEMICAL CONTROL

It is readily apparent from a quick review of the considerations on mechanical control, that there is no efficient physical method for controlling submerged or free floating species. In the control of these plants, chemicals are most effective.

Many factors must be taken into consideration before a chemical control is used for water weeds. Caution should be used in applying any of the inorganic poisons in the Mekong region. Two of the main crops of this region are rice and sugar cane and both of these crops require quite extensive irrigation.

The inorganic poisons are highly soluble in water, do not tend to break down, and can be transported over great distances with the treated water. As a general rule, these poisons are more damaging to cultivated crops than the weeds for which they are intended. Viste (1962) however has shown how the organic DPA (3,4-Dichloropropionanilide) can selectively control the water-grass, Echinochloa crusgalli, in rice when used as a foliage spray.

Before applying any chemical, one must know the volume of water to be treated, and its rate of flow. There are many formulae in use for finding this information, but the easiest to handle seems to be Chancellor's (1958).

Calculation of volume and weight of water:
AREA X DEPTH X 6.2 X 10 = WEIGHT IN lbs.
(6.2 gallons of water = 1 cu. ft. and 1 gal. water weighs 10 lbs.)
Calculations of the rate of flow of running water:
AVERAGE WIDTH X AVERAGE DEPTH X MEAN VELOCITY = RATE OF FLOW (cu. ft./sec.)

A general rule of thumb for treating moving water is: if less than 15 percent of the volume to be treated is changed in one week, it can be considered still water for organic treatments, and if less than 20 percent is changed in one week, it can be considered still water for inorganic poisoning (Roberto, Noll, and Mussell, unpublished).

The chemicals available for control of hydrophytic vegetation are generally of two types, the inorganic poisons, which control by direct killing of the plant cells, and the organic growth modifiers, which control by altering some vital process in the plant, usually meristematic activity or respiration. The organics, as a general rule, are safer to use when there is any danger of the water's being used for irrigation or animal consumption. The organics are not as toxic to animals as the inorganic poisons, and a greater quantity of an organic is usually needed to be detrimental. Conversely, less of the inorganic poison is needed to be deleterious to animals, while a greater concentration is needed to kill the plants. Another argument in favor of the organics is the fact that none of them are cumulative, and they tend to break down after a variable length of time. The inorganic poisons, on the other hand, are usually cumulative, (Robbins et al, 1952) and do not tend to break down in the water or residual soil.

AVAILABLE CHEMICALS

POISONS

SODIUM ARSENATE: This chemical is highly toxic to animals at moderately low concentrations, and should be used with extreme caution.

Every sample of sodium arsenate sold states the arsenic trioxide equivalent, As 0, and this should be noted, because the formulations differ somewhat (Chancellor, 1958). The volume of water to be treated must be carefully measured in length, width, and depth (in feet). A convenient formula for these computations is:

$$\frac{\text{VOLUME (in cu. ft.) X 62.4}}{1{,}000{,}000}$$ NUMBER OF LBS. ARSENIC TRIOXIDE NEEDED FOR A CONCENTRATION OF 1 P.P.M.

This figure times the number of parts per million needed fôr treatment will give the number of pounds of arsenic trioxide needed.

Sodium arsenate has been found effective for most types of floating weeds, almost all submerged species, and a few emergent types. The recommended dosage varies with local conditions from 3 to 7 p.p.m., and should never exceed 10, because this is the threshold level for toxicity to animals and fish (Chancellor, 1958). Sodium arsenate should only be used in cases where everything else has failed.

<u>SODIUM CHLORATE</u>: The reports on this chemical state that it will kill the exposed parts of many emergent species, and the floating leaves of pondweeds and water lilies; but the treatment does not kill these plants, and they will resprout from the rootstocks. No information is available for the effects of this chemical on free floating species, but it is doubtful that it will have much effect. The recommended concentration for this chemical is 2.5 percent solution with a wetting agent added. In the concentrations used to kill weeds, this chemical is non-toxic to fish and animals. <u>Caution</u>, any clothing on which sodium chlorate is spilled should be destroyed immediately, as it will become highly flammable, bursting into flame upon exposure to the sun.

<u>COPPER SULFATE</u>: The continued use of this chemical for control of aquatic vegetation is questionable, since so many other chemicals will do the job just as well, in lower concentrations, with fewer applications.

<u>ORGANIC CONTROLS</u>

<u>MONURON</u>: This chemical is a chlorinated ureic phenyl, that is generally applied in granular form, and is of low solubility in water. It is especially effective on the deeply rooted floaters and emergents (British Weed Control Council). The recommended rate for complete eradication of emergent species is 50 lbs. (dry wt.) per acre of surface. At this concentration, it is non-toxic to fish and animals.

<u>MCPA</u> (4-chloro-2-methyl-phenoxyacetic acid), <u>2-4-D</u> (2-4-dichlorophenoxyacetic acid), <u>2-4-5-T</u> (2-4-5-trichlorophenoxyacetic acid).

These three chemicals were among the first organic herbicides developed, and are still the most popular for both aquatic and terrestial plants. 2-4-D and MCPA are more effective over a broader range of species, while for some particularly resistant species 2-4-5T is most effective. All three are usually applied in emulsifiable oil solutions of their esters, the oil solution acting as a good penetration agent on floating leaves, and emergent species. It is recommended that these chemicals be applied after the period of most vigorous growth when the food reserves of the plant are low. The effects of these chemicals are such that the killed plants are very susceptible to maceration by even the slightest agitation of the water (Mussell, unpublished). These individual cells will present no hazard to navigation, only adding a slight turbidity to the water, and lowering the dissolved oxygen content somewhat. The recommended rates fall between 6 to 12 lbs. acid equivalent, and at these rates, there is no danger to fish or animals.

TRICHLORACETIC ACID: This chemical is used for the control of emergent reeds, but is fast being replaced by the more effective Dalapon.

DALAPON: This chemical, a halogenated aliphatic acid, is a systemic herbicide, i.e., it is absorbed by the leaves of the plants and translocated to the roots where it takes effect. It is particularly effective for anchored floaters or emergent species, especially those growing in running water. The chemical is applied as an aqueous solution, and the application of a wetting agent to the formula is recommended.

MALEIC HYDRAZIDE: This chemical, although not commonly used as a weed control at the present time, presents what might be the ultimate in control of Monocotyledenous reeds and rushes. It is a growth inhibitor for Monocots that seems to be almost 100 percent effective in stopping resprouting of plants that have been partially killed by other means (B.W.C.C. 1960).

RECOMMENDATIONS FOR WEED CONTROL

In consideration of control measures to facilitate boat traffic in the Mekong region, emphasis will be placed on ecologic associations rather than individual genera, because the plants encountered will not be individuals, but groups; and control or suppression of the dominant species in each association will greatly facilitate boat travel, while not requiring a multitude of different treatments. Mention of specific genera will be confined to plants which present specific problems in control or can be dealt with relatively easily.

There should be no problem whatsoever in obtaining 100 percent control of the bladderwort community (Utricularia flexuosa association). The majority of the species in this association that will obstruct boat traffic are rootless submerged species that will respond excellently to treatment with an emulsion of 2-4-D in concentration of 3 to 12 p.p.m., depending on water conditions. There will also be no problem in disposal of the killed weeds because as they die, they will decompose and disintegrate into microscopic particles. The recommended rates of 2-4-D will not be harmful to either fish or animal life, however, there might be a small amount of fish-kill due to lowering of the dissolved oxygen content of the water as the plants decompose. This will be a problem only in still water. If applied before the flowering season, this treatment should be effective for one growing season.

The basic problem in alleviation of the impediment presented to water traffic by the water lily community (Nymphaea stellata association) is not in killing the plants, but disposal of the dead parts, especially the stalks which become very tough and rope-like, fouling propellors. The best way to attack this problem is to drag the area with a chain to remove all submerged and floating parts, then treat with an aqueous solution of Dalapon (still water), or pelletized monuron (running water), to inhibit resprouting from the rootstocks. This treatment should be effective for one growing season and if applied before the plants have set seed, perhaps longer. Unfortunately, there are no really effective seed killers so that a re-application of the required chemicals will be needed after each seed fall.

Two types of plants occur in the duckweed community (Lemna-Wolffia association), free floaters and anchored floaters. The anchored floaters of this association will have to be dragged as was recommended for the previous association. After dragging, both free floaters and the rootstocks of the anchored plants will respond favorably to treatment with Dalapon.

The sedge community (Cyperus-Eleocharis association) is composed of many types of hydrophytes, but only one extra treatment will be needed to control them. The sedges, Cyperus spp. and others with long emergent stems, can be burned before the chemical treatment. After burning, a mixed treatment of either 2-4-D or MCPA and maleic hydrazide will kill the remaining shoots and most of the other vegetation, also inhibiting resprouting. This treatment should be good for one growing season, and after treatment for two consecutive seasons, no further treatment should be necessary.

The Nipa palm community (Cryptocoryne-Acanthus association) is the most difficult to control. Because of the many woody species found in this association, the problem is not killing them but removing the woody stems. No work has been done on removal of woody hydrophytes, but it is common practice in the southeastern United States to remove undesirable tree species by dragging with heavy anchor chains. Any place where the tractors can get traction, this should work for hydrophytes as well. Success has been reported with trees up to 14 inches in diameter (Duke School of Forestry, 1958). Once the woody species are removed, the control measures are similar to those for other predominantly emergent species.

Although it is not yet in a useable form, the laeser light has been shown to be highly efficient in cutting and destroying woody tissues (Bryan, 1963), and if the optics of this system can be overcome, it may be the ultimate answer to controlling woody vegetation.

According to Potapov (1960), reeds (Phragmites sp.) and cattails (Typha sp.) are easily eliminated by mowing three to four times during the season. Chancellor (1958) notes that the seeds of these species will not germinate under water, so that flooding might be considered to prevent reentry into the mowed area.

SUMMARY AND RECOMMENDATIONS

1. The soils and climate of South Vietnam are such that the terrestrial vegetation is quite unlike that of Virginia, but marine, brackish and fresh-water floras of the two areas are not so different. Several genera and a few species of aquatic plants are common to both areas.

2. Of the major types of aquatic vegetation, i.e., submerged, anchored floaters, free-floaters, emergent herbs, shrubs and trees, all are to be found in Virginia except analogues of the palm swamps and the mangroves, and these would be accessible to boats only at high tides. Cypress swamps are roughly analogous to mangroves except that stilt roots are lacking.

3. Florida has mangrove swamps and Panama has both mangrove and palm swamps, so it is probable that the Atlantic Coast of Panama would more closely resemble Viet Nam as regards aquatic vegetation. Tides on Panama's Pacific Coast are of such magnitude that few herbaceous aquatics develop in the tidal rivers. Floating beds of water hyacinth are reported from Gatun Lake. Laguna Matusagrati in Darien might be investigated as an analogue of the Nipa palm swamp. Mangrove forests of Panama are quite similar to those of Viet Nam although not composed of as many different species and not attaining quite so great a height.

4. Rice fields are navigable by boats in the rainy season. As a matter of fact much of the rice is harvested in boats. In the dry season, most of them are drained and become hard and dry and navigable by jeep. Some of the salt marshes of tidewater Virginia might be comparable to the sedge marshes of Viet Nam which are cleared to make rice paddies. Flooded savannas of the Pacific Side of Panama would probably be a closer analogue for flooded rice paddies.

5. There is not much in the literature about the tensile strength and other physical features of aquatic plants that would interfere with hydrotrafficability so that is difficult to access the obstacles that uninvestigated species would offer. The amazingly strong fibers which persist after the dying down of Peltandra and Pontederia of the southeastern United States are not even mentioned in the literature consulted in this investigation.

6. For general purposes water weeds may be classified as submerged, floating, and emergent, and these three categories offer different obstacles to boats. Submerged plants may form submarine meadows or freshwater meadows which may foul the lower reaches of the propellors. Floating species may be anchored or free floating. Among the free floating species are very small (microphyllous) and large-leaved (macrophyllous) plants. The microphyllous species are known collectively as duckweeds and the only problem they offer to boats is in clogging up the water systems. On the other hand the macrophyllous free-floating species such as water hyacinths may retard speed, increase gas consumption, and occasionally hanging roots may foul propellors. Sometimes these form such dense floating islands that water traffic is virtually impossible without frequent clearing of the props, etc. Attached floaters are usually anchored to the bottom by rope-

like stalks which tend to wrap around propellors to such an extent as to cause stoppage. Most emergent species grow in water so shallow that water traffic would not be recommended except at high tides and during floods but they frequently form stands with 100 percent coverage which would cause frequent stoppages even if they could be penetrated.

7. Most means for controlling aquatic weeds are rather slow, but some of the emergents can be eliminated or decimated by burning at low tides. Rice paddies are intentionally burned in some parts of Viet Nam. Chemical means usually take a matter of weeks, and perhaps would be ineffective in speeding the decomposition of tough dead fibers such as those of the pickerel weed. In the brackish waters of the Mekong Delta, currents would almost continually be bringing down new floating islands of vegetation as they washed away any chemicals being used for control.

8. New data on the tensility of aquatic plants, on the reaction of aquatic plants to flame-throwers, on the conversion of submerged rhizomes to edible products, on the phenology of aquatic plants, and on the decomposition of aquatic plants are certainly to be desired.

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COMMON NAME	SCIENTIFIC NAME	PAGE REF.	FIGURE
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Arrowhead	Sagittaria	31	
Australian Pine	Casuarina	20	
Barnyard Grass	Echinochloa	32, 55	
Black Mangrove	Avicennia	16	5
Bladderwort	Utricularia	43, 57	
Buffalo Nut	Trapa	31, 41	13
Bull Rush	Juncus	54, 57	
Cattail	Typha	23, 49, 54	8
Chinese Arrowhead	Sagittaria	31	8
Coontail	Ceratophyllum	43, 52	14
Custard Apple	Annona	23, 37	7
Duckweed	Lemna etc.	41, 52, 57	
Eel Grass	Vallisneria	13, 43	14
Floating Fern	Salvinia	41	
Loosestrife	Decodon	37, 52	
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Mangrove Fern	Acrostichum	22	7
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Morning Glory	Ipomaea	31, 39	12
Naiad	Naias	39, 43, 61	
Nypa Palm	Nipa	19, 20, 21, 22, 23, 58	7
Pickerel Weed	Pontederia	49, 52, 59	
Poison Bulb	Crinum	23	7
Pond Weed	Potamogen	13, 56	
Red Mangrove	Rhizophora	16	5
Reed	Phragmites	54, 57, 58	
Rice	Oryza	31, 54	
Sea Grape	Coccoloba	3	
Sea Grass	Cymodocea etc.	13	4
Sea Lettuce	Enteromorpha	13	
Screw Pine	Pandanus	37	6

TABLE 13: INDEX TO ENGLISH COMMON NAMES OF AQUATIC PLANTS

Sedge	Cyperus etc.	28, 53, 58	8 & 9
Spatterdock	**Nuphar**	52	
Sugarcane	**Sachharum**	28, 54	
Sweet Flag	**Acorus**	31	
Tape Grass	**Vallisneria**	39, 43	14
Turtle Grass	**Thalassia**	13	4
Velvetleaf	**Limnocharis**	32	8
Water Chestnut	**Eleocharis**	31	9
Water Chestnut	**Trapa**	31, 41	13
Water Fern	**Ceratopteris**	37	8
Water Grass	**Echinochloa**	32, 55	9
Water Hyacinth	**Eichornia**	39, 41, 49, 54, 59	13
Water Lettuce	**Pistia**	39, 41	13
Water Lily	**Nymphaea**	39, 56	12
Water Lotus	**Nelumbium**	31	12
Water Mimosa	**Neptunia**	37, 39	12
Water Primrose	**Jussiaea**	32	
Water Shield	**Brasenia**	52	
Water Weed	**Elodea**	52	
Water Wort	**Elatine**		
Widgeongrass	**Ruppia**	13	
Wild Rice	**Zizania**	33	