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PART B: WORKING PAPERS

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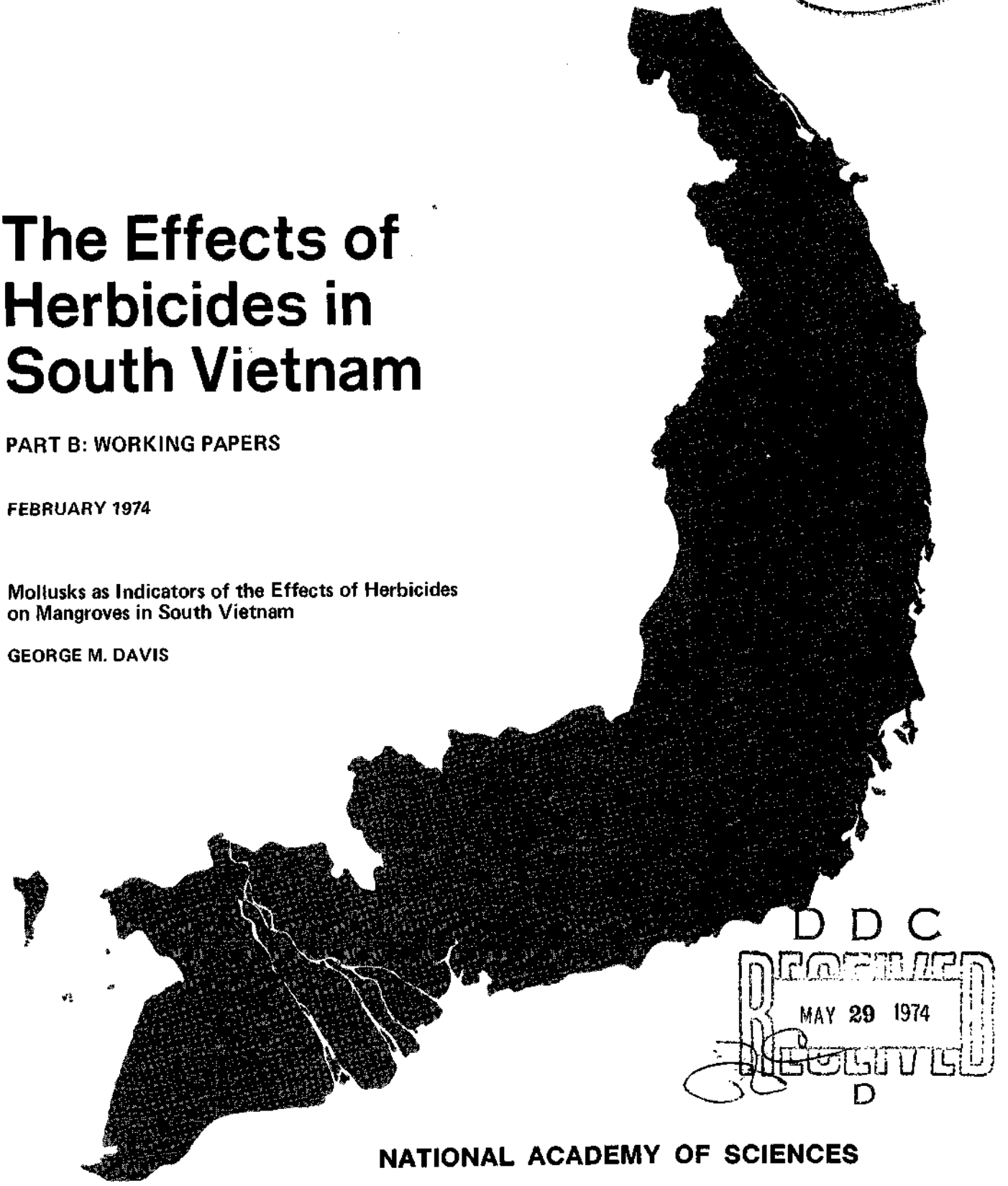

NATIONAL ACADEMY OF SCIENCES

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GEORGE M. DAVIS

NATIONAL ACADEMY OF SCIENCES - NATIONAL RESEARCH COUNCIL

WASHINGTON, D.C. 20418

Mollusks as Indicators of the Effects of Herbicides on Mangroves in South Vietnam

GEORGE M. DAVIS[a]

The Rung-Sat Special Zone is comprised of about 360 square miles (932 km^2) of mangroves. The northern limit of the zone is 10 miles (16 km) on a direct line from the center of Saigon. Mangroves extend 20 miles (32.2 km) due south to the South China Sea. A southeastern extension of the mangroves reaches the Vung-Tau Peninsula (Cap Saint Jacques). The two areas, the Rung-Sat and Vung-Tau, comprise about 400 square miles (1036 km^2).

United States military forces engaged in defoliating the Rung-Sat Special Zone between the years 1966 and 1969. A total of 545,105 gal of Agent Orange and 225,485 gal of Agent White were sprayed over the mangroves. The mangroves were secondary, having been heavily lumbered for some years. Agent Orange is a mixture of 2,4-D and 2,4,5-T; Agent White, a mixture of 2,4-D and picloram (Tordon). An average of 2.1 gal was sprayed per acre. The result was massive defoliation, subsequent lumbering off the dead trees by the Vietnamese, and the reduction from mangrove to barren mud flats.

The purpose of this report is to assess the effects of the defoliants on the Rung-Sat four years after cessation of spraying and to determine the long-term consequences of the defoliation program in that area.

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The molluscan fauna of the Rung-Sat-Vung-Tau area is discussed in terms of number of species, diversity of fauna, and faunal ecology. The diversity of Southeast Asian mangrove mollusks relative to numerous types of ecological niches makes this group of organisms particularly valuable for studying the effects of any type of alteration of the natural mangrove.

METHODS

No data on the molluscan fauna of the Rung-Sat prior to defoliation were available. Therefore, a control area that was not defoliated was selected on the Vung-Tau Peninsula. A section of this control area had been sprayed with Agent Orange on March 17, 1972 as an experiment sponsored by the National Academy of Sciences to assess the effects of defoliation under controlled conditions. The area sprayed was small and well-marked; however, the one-time operation had no apparent effect on the mangrove; i.e., leaves did not fall, trees were not killed.

Collections were made from 20 stations (Figure 1). The collection dates and localities are given in Table I. Sites in the Rung-Sat (Stations 1 to 12) were reached by river patrol boats provided by the South Vietnamese Navy. Two boats were used. Dr. de Sylva (Committee consultant from the University of Miami) used one to collect fish and take water samples. The author's land collections were made close to de Sylva's stations (Table I). Due to security reasons, all land collections were limited to 20- to 40-minute intervals. No penetration inland was made beyond 150 yd (137 m).

Collections were made by three people in the allotted time interval.

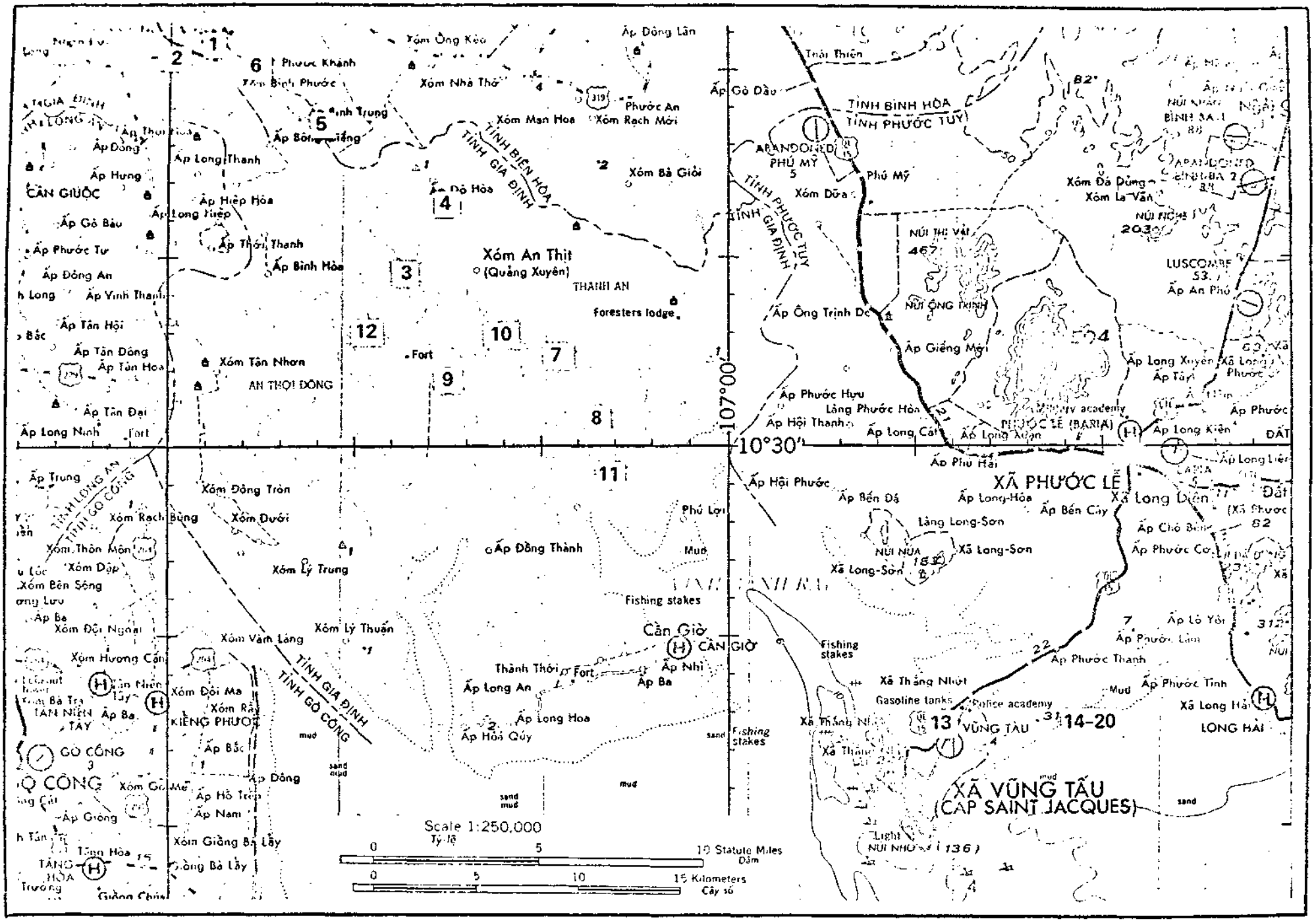

FIG. 1. Location of collecting stations in the Rung-Sat Special Zone and Vung-Tau Region, January-February, 1973.

Table I.

Dates and coordinates of localities where molluscan collections were made in the Rung Sat Special Zone and Chi-Linh, Vung-Tau Peninsula.

Date (1973)	Dr. Davis' Field Coll. No.	This Report Station No.	Dr. deSylva's Coll. No.	Map Coordinate[a]	Longitude & Latitude[b]
Jan. 18	D73-2	1	---	XS9380	106°46' lon. 10°40' lat.
Jan. 18	D73-3	2	---	XS9280	106°46' 10°41'
Jan. 22	D73-5	3	VND; 60-61	YS0369	106°52' 10°34'
Jan. 22	D73-6	4	VND; 62-63	YS0574	106°53' 10°37'
Jan. 22	D73-7	5	VND: 64-65	XS9977	106°49' 10°39'
Jan. 22	D73-8	6	VND; 66-67	XS9579	106°48' 10°40'
Jan. 23	D73-9	7	VND; 68-69	YS1165	106°56' 10°32'
Jan. 23	D73-10	8	VND; 70-71	YS1363	106°56 10°31'
Jan. 23	D73-11	9	VND; 72-73	YS0664	106°53' 10°32'
Jan. 23	D73-12	10	VND; 74-75	YS0867	106°54' 10°33'
Jan. 24	D73-13	11	VND; 76-77	YS1460	106°57' 10°29'
Jan. 24	D73-14	12	VND; 80-81	YS0267	106°51' 10°33'
Jan. 30	D73-21	13	VND; 100-101	YS2948	107°06' 10°22'
Jan. 31	D73-25	14	---	YS3649	107°10' 10°23'
Jan. 31	D73-26	15	---	"	"
Jan. 31	D73-27	16	---	"	"
Jan. 31	D73-28	17	---	"	"
Feb. 1	D73-29	18	---	"	"
Feb. 1	D73-30	19	---	"	"
Feb. 1	D73-31	20	---	"	"

[a]U.S. Army Map Service, Series 1501, Sheet NC 48-7, Ed. 2.

[b]to closest minute.

The types of mollusks collected were noted along with the microhabitat condition. Living and dead plant species were recorded, with careful attention being given to both currently-living plants and those that were the dominant species prior to defoliation. Tree stumps could be readily identified to genus. Plants served as indicators for steady-state ecological conditions. More information could be derived from knowledge of these species than from measurements of temperature, salinity, etc. taken at one spot at one point in time.

Mollusks were picked by hand or were obtained with the aid of sieves. As many specimens, both living and dead, were taken as the time span allowed. All specimens were preserved in 70 percent ethyl alcohol.

Station Characteristics

Stations 1, 2, and 6 were at the northern edge of the Rung-Sat Special Zone. The dominant tree was Nypa fruticans. Sedges were common (Cyperus); the region was dominated by rice fields.

Stations 3 to 5 and 7 to 12 were in the Rung-Sat mangrove proper where the land was elevated no more than 6 ft (1.8 m) and was completely covered by high tides during June-July and December-January. During normal high tides 85 percent of the land was under water.

Two high and two low tides occurred every 24 hours. The average high tide was 3.3 m. The slope of the water course was about 2 cm/1000, a fact that explains why salt water invaded the region 111 miles (185 km) north of Vung-Tau. The soil was predominantly clayey and acidic, and also contained sodium sulfite.

Station 13 was a managed mangrove of Avicennia officinalis. The

trees were uniformly 14 to 16 ft high (4.3 to 4.8 m) and evenly spaced.

Stations 14 to 20 were in Chi-Linh, where the mangrove developed in a southwesterly direction along a river that emptied into the mouth of the Rach-Cua-Lap River. The mangrove, about 1 mile (1.6 km) wide in the region of the collections, was bounded on one side by sand dunes and on the other by farm lands. Thus, within a very short distance were found dry areas flooded only occasionally by salt water and areas inundated twice a day.

A list of the 28 plants recorded as prominent species is given in Table II. This table should be referred to in the following characterization of each station.

RESULTS

Molluscan Fauna

A compilation of the species of mollusks collected is given in Table III. Of the 42 species collected, three were bivalves, the remainder gastropods. All subclasses of gastropods were represented and all orders of the subclass Prosobranchia were represented.

Twenty-one species (50.0%) were collected alive from both the defoliated and control areas (Table IV). As shown in Table V, four species were found only in the Rung-Sat while 15 were found only in the Vung-Tau control region. One species, the bivalve Enigmonia aenigmatica, was found living only in the region north of the defoliated areas in slightly brackish water and thus was excluded from the comparison between the Rung-Sat and Vung-Tau.

The 20 most common species found in the survey are listed in Table

Table II. Dominant plants found at one or more of the 20 stations of this study. Station numbers follow species names.

Pteridophytes

Polypodiaceae

1. Acrostichum aureum L. 3,4

Spermatophytes (dicots)

Euphorbiaceae

2. Excoecaria agallocha L. 19,20

Meliaceae

3. Xylocarpus sp. 7,9,11,12,15,19

Papilionaceae

4. Derris sp. 4

Rhizophoraceae

5. Rhizophora apiculata Bl. 14,17,18
6. Rhizophora sp. 7
7. Ceriops sp. 7,14,15,18,19,20
8. Ceriops decandra 9

Sonneratiaceae

9. Sonneratia caseolaris (L.) 8,9
10. Sonneratia sp. 9
11. Barringtonia acutangula Gaertn.
12. Melaleuca leucadendron L.

Combretaceae

13. Lumnitzera racemosa Willd. 20

Acanthaceae

14. Acanthus ebracteatus Vahl. 4

Bignoniaceae

15. Dolichondrone spathaceae K. Sch. 4

Verbenaceae

16. Avicennia alba Bl. 3,7,14
17. Avicennia officinalis L. 8,9,13,14
18. Avicennia sp. 8,10,11,12,17,18

Compositae

19. Wedelia biflora D.C. 4

Spermatophytes (monocots)

Flagellariaceae

20. Flagellaria indica L. 5

Gramineae

21. Paspalum vaginatum 3,4,5,8,9,10,12
22. Panicum repens 4,5

Cyperaceae

23. Cyperus malaccensis Lam. 3,4,5,6
24. Cyperus tagetiformes 6
25. Fimbristylis polytrichoides 8,10

Palmae

26. Nipa fruticans Wurmb. 1,2,4
27. Phoenix paludosa Roxb. 9,16,20

Aizoaceae

28. Sesuvium portulacastrum L. 8,9

Table III.

Systematic arrangement of mollusks found during this study, their location by station, and whether they were living (L) or dead (D).

Mollusk Species	Station Numbers[a]																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
GASTROPODA																				
Subclass Prosobranchia																				
Order Neritogastropoda																				
Family Neritidae																				
1. Nerita lineata Gmelin			L				L	L	L	L	L	L	L	L			L	L	L	
2. Dostia violacea (Gmelin)	L	L	L	L	L	L	L	L			L	L		L	L			L	L	
3. Neritodryas dubia (Gmelin)	L	L													L		L			
Order Mesogastropoda																				
Family Lacunidae																				
4. Mainvaringia sp.								L			L							L		
Family Littorinidae																				
5. Littorina melanostoma Gray			L				L	L	L	L	L	L	L	L				L		
6. Littorina scabra Linne			L	L			L	L	L	L	D	L	L	L		L	L	L	L	
Family Stenothyridae													L							
7. Stenothyra monilifera Benson																		L		
8. Stenothyra quadrasi Möllendorff															L		L	L		
Family Assimineidae																				
9. Assiminea brevicula (Pfeiffer)			L				L	L	L	L	L	L	L	L	L		L	L		
10. Assiminea sp. nov. (No. 1)			L					L	L			L								
11. Assiminea sp. 2		L									L		L							
12. Assiminea sp. 3											L					D				
Family Iravadiidae																				
13. Fairbankia cochinchinensis Bavay & Dautz.														L						
14. Iravadia ornata Blanford												L								
15. Iravadia reticulata Brandt												L		L				L		
Family Potamididae																				
16. Cerithidea alata (Philippi)						L	L	L	L	L	L	L	L	L			L	L		
17. Cerithidea cingulata (Gmelin)												L	L			L	L	L		
18. Cerithidea obtusa (Lamarck)	L		L	D		L	L	L		D	L		L			L	L	L		
19. Cerithidea quadrata Sowerby						L	L	L	L	L		L	L			L	L	L		
20. Cerithidea moreleti Wattebled.						L		L		L						L				
21. Batillaria multiformis Lischke.																L				
22. Terebralia sulcata (Born)																L				
Order Neogastropoda																				
Family Muricidae							L	L		L		L								
23. Murex (Naquetia) capucinus Lamarck																				
Family Buccinidae		L				L	L	L	L	L	L	L	L			L	L			
24. Engina duclosiana Sowerby																				

Table III, Continued.

Mollusk Species	Station Numbers[a]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Family Nassariidae																				
25. Nassarius aff. olivaceus Brug.							L					L	L							
Subclass Pulmonata																				
Family Ellobiidae																				
26. Auriculastra subula (Quoy & Gaimard)			L	L			L											D		
27. Cassidula aurisfelis (Brug.)														L			L	L	L	
28. Cassidula faba (Menke)							D						L	L				L		
29. Cassidula nucleа (Gmelin)														L			L		L	
30. Ellobium auris-judae (Linné)			L			L	L	L		L	L	L				L	L	L	L	
31. Laemodonta decussata (H. & A. Adams)																		L		
32. Laemodonta punctatostriata (H. & A. Adams)			L	L			L	L	L			L						L		
33. Laemodonta punctigera (H. & A. Adams)			L	L			L	L				L		L				L	L	
34. Melampus siamensis von Martens	L		L	L		L		L				L						L	L	
35. Phytia plicata (Fer)			L	L		L														
36. Phytia trigona (Troschel)								D								D				
Family Amphibolidae																				
37. Amphibola quadrasi (Möllendorff)															L			L		
Subclass Opisthobranchia																				
Order Cephalaspidea																				
38. Haminoea sp.											L									
Order Onchidiacea																				
39. Onchidium spp.	L		L	L		L							L	L				L	L	
BIVALVIA																				
Family Anomiidae																				
40. Enigmonia aenigmatica Holten	L										D									
Family Corbiculidae																				
41. Polymesoda (Geloina) coaxans (Gmelin)			D	L			L			D	D									
Family Teredinidae																				
42. sp.								D		D	D									

[a]Stations 13 to 20 in control mangrove, Vung-Tau Peninsula.

Table IV.

Species of mullusks found in both the Rung-Sat and Vung-Tau.

	Species	Occurrence[a]
1.	Nerita lineata Gmelin	C
2.	Dostia violacea (Gmelin)	C
3.	Neritodryas dubia (Gmelin)	FC
4.	Mainvaringia sp.	FR
5.	Littorina melanostoma Gray	C
6.	Littorina scabra Linné	C
7.	Assiminea brevicula (Pfeiffer)	C
8.	Assiminea sp. 2	R
9.	Cerithidea alata (Philippi)	C
10.	Cerithidea obtusa (Lamarck)	C
11.	Cerithidea quadrata Sowerby	C
12.	Cerithidea moreleti Wattebled.	FR
13.	Engina duclosiana Sowerby	FC
14.	Murex capucinus (Lamarck)	C
15.	Nassarius aff. olivaceus Brug.	R
16.	Ellobium aurisjudae (Linné)	C
17.	Laemodonta punctatostriata (H. & A. Adams)	C
18.	Laemodonta punctigera (H. & A. Adams)	C
19.	Melampus siamensis von Martens	C
20.	Onchidium (two species)	C

[a] C = common; many found at several stations.

FC = fairly common, a few found at 3 or 4 stations.

FR = fairly rare, one or two found at 1 to 4 stations.

R = rare, one to three specimens found total.

Table V.

Species found only in the Rung-Sat or only in the Vung-Tau control mangrove.

	Rung-Sat	Vung-Tau
1.	*Assiminea* sp. nov.	*Stenothyra monilifera*
2.	*Haminoea* sp.	*Stenothyra quadrasi*
3.	*Phytia plicata*	*Fairbankia cochinchinensis*
4.	*Polymesoda* (*Geolina*) *coaxans*	*Iravadia ornata*
5.		*Iravadia reticulata*
6.		*Cerithidea cingulata*
7.		*Cerithidea moreleti*
8.		*Batillaria multiformis*
9.		*Terebralia sulcata*
10.		*Cassidula faba*[a]
11.		*Cassidula aurisfelis*
12.		*Cassidula nuclea*
13.		*Laemodonta decussata*
14.		*Phytia trigona*[b]
15.		*Amphibola quadrasi*

[a] only a dead shell found in the Rung-Sat.

[b] only a dead shell found.

VI along with their occurrence in the Rung-Sat and Vung-Tau. To qualify for this list the species must have been collected alive, in good quantity (more than 10 to 20 specimens at one locality), and at more than one station.

Station by Station Analysis

Station 1. Dostia violacea was common on rocks and wood pilings in the river at Nha-Be (accessible at low tide). On higher ground behind homes in the village of Nha-Be we collected Neritodryas dubia from the water at the base of Nypa palms.

Station 2. Collections were made along a transect from Route 15 (from Nha-Be to Saigon) to the river. The area was dominated by rice fields. Low, swampy, uncultivated areas had Nypa palms. The unique bivalve Enigmonia aenigmatica was found molded to the concave curvature of the Nypa fronds. Populations of this species were spotty and few.

In the least brackish areas Dostia violacea and Neritodryas dubia were found. A spotty distribution of Cerithidea obtusa was discovered at the edge of vegetation beside a meandering stream draining the rice fields and flowing into the river.

Station 3. Near the edge of the river were broad expanses of the grass Paspalum vaginatum in which were found both Assiminea brevicula and Assiminea sp. 1. Littorina melanostoma was found clinging to the grass stems. Ellobiid snails were found on the mud at the base of the stems of grass.

Associated with the marsh fern, Acrostichum aureum, were Phytia plicata and other ellobiids. Digging under decaying wood revealed Ellobium aurisjudae while Nerita lineata was found on the decaying wood.

Table VI.

A list of the 20 most common molluscan species in the Rung Sat-Vung Tau region.

	Most Common Species	Rung-Sat	Chi-Linh - Vung Tau
1.	Nerita lineata	+	+
2.	Dostia violacea	+	+
3.	Littorina melanostoma	+	+
4.	Littorina scabra	+	+
5.	Stenothyra quadrasi	-	+
6.	Assiminea brevicula	+	+
7.	Iravadia reticulata	-	+
8.	Cerithidea alata	+	+
9.	Cerithidea cingulata	-	+
10.	Cerithidea obtusa	+	+
11.	Cerithidea quadrata	+	+
12.	Murex capucinus	+	+
13.	Engina duclosiana	+	+
14.	Ellobium auris-judae	+	+
15.	Laemodonta punctatostriata	+	+
16.	Laemodonta punctigera	+	+
17.	Melampus siamensis	+	+
18.	Phytia plicata	+	-
19.	Onchidium	+	+
20.	Polymesoda coaxans	+	-

+ = present
- = absent

Stretching beyond the river fringe with its spotty patches of Acrostichum, Cyperus malaccensis, and Avicennia alba was a vast plain of mud dotted by decaying tree stumps. At the base of these stumps were numerous Murex capucinus, predator of both Nerita lineata and species of Cerithidea. (Cerithidea was not found at this location.) Dotting the mud flats were whitened shells of dead Polymesoda (Geolina) and Murex.

Station 4. This locality was dominated by vast fields of the sedge Cyperus malaccensis, with some marsh grass Panicum repens and Acrostichum. There were also a few plants of Wedelia and Derris near the shore, Dolichandrone and Acanthus.

Laemodonta punctigera and L. punctatostriata were found on the soil throughout the fields of Cyperus. Phytia plicata was found with rotting wood under the Acrostichum along with Onchidium sp. A single specimen of Cerithidea obtusa was found in the fields of Cyperus. Dostia was found under logs in very wet areas.

Station 5. Cyperus dominated the locality along with dense stands of Panicum repens. The fields of Cyperus were evident for a half mile (0.8 km) away from the river. Phytia plicata and Ellobium aurisjudae were found under decaying vegetation. Melampus siamensis was found on the mud in the Cyperus fields.

Station 6. Rice fields extended down to the edge of the river where low dikes held the river back. Between the dikes and the river were mixed stands of Cyperus tagetiformes and C. malaccensis. On the mud at the edge of thick stands of the sedges were thousands of Onchidium sp. and some Dostia.

Station 7. Vast acres of mud were dotted by stumps of Xylocarpus (dominant), Avicennia (numerous), Rhizophora and Ceriops (some). Some living Ceriops were found; small plants 1 to 2 ft high dotted the area. Soil and air temperatures were 94°F and 86°F, respectively. Snails were very abundant.

Paspalum grass supported Littorina melanostoma. Assiminea was found on the exposed mud both in the open areas and at the base of dead stumps. Ellobium and Auriculastra were, as usual, found under decaying wood piled up about living Ceriops.

The base of decaying stumps supported Murex, Nerita, and Cerithidea obtusa. Littorina scabra was found above the soil on the roots of dead and living plants. Nassarius occurred in a small drainage stream. The mud was dotted with dead shells of Polymesoda (Geolina). Cerithidea alata and C. quadrata were found on the mud near vegetation.

Station 8. Stretching away from the river were thousands of acres of barren mud dotted only by stumps of Avicennia and some Xylocarpus. Near the river bank was a grove of living Avicennia officinalis, with a few small plants of Sonneratia caseolaris. There were thin patches of Paspalum grass as well as Sesuvium portulacastrum. Here and there some Fimbristylis polytrichoides was present.

In the shade of the grove of trees were Littorina scabra, Murex, Nerita, Cerithidea obtusa, and C. quadrata. Exposed mud surfaces bore Assiminea and Melampus. Engina was found in shallow drainage streams. No Polymesoda (Geolina) or Ellobium were discovered.

Snails common on trees were Murex, 1 ft (0.3 m) above ground; Nerita 1-3 ft (0.3-0.9 m) above ground; Cerithidea, to 3 ft (0.9 m) above ground;

and Littorina scabra, to 4 ft (1.2 m) above ground.

Station 9. The situation was similar to that at Station 8. Living Avicennia officinalis was present in a limited number of small stands, 3 to 4 trees per stand. Fimbristylis, Sesuvium, and Paspalum were found in small patches. One living Xylocarpus was noted. Ceriops decandra was present in small numbers.

Assiminea brevicula and Littorina melanostoma were associated with the Paspalum grass. In the shade of the Phoenix, Sonneratia caseolaris, and Avicennia were Nerita, Cerithidea, Murex, and Littorina melanostoma. On the exposed mud were Murex, Assiminea, and Littorina scabra (the last on dead tree stumps). On the living trees (1-3 ft above ground) were Cerithidea, Littorina melanostoma, and Nerita. Engina was found in a small drainage stream.

Station 10. Extensive carpets of Paspalum grass grew along the edge of the river. Beyond the grass was an expanse crowded with huge stumps about 15 ft (5 m) apart. These were primarily Avicennia, rotted in the middle and housing Ellobium in the rotted wood.

Littorina melanostoma was common on the grass while Assiminea brevicula was found on the mud, both in grassy or exposed areas. Murex was common at the base of the dead stumps.

Station 11. Hundreds of acres of dead stumps of Avicennia and Xylocarpus were found. This site was used by Dr. Teas (Committee consultant from the University of Miami) for experimental planting of Rhizophora and Ceriops. During our examination there was about a 50 percent survival; Rhizophora was growing faster than Ceriops.

Two large living Avicennia trees stood in the collection site; on the

mud beneath them were numerous Haminoea. Many Nerita, Littorina melanostoma, Murex, and Cerithidea were seen on the trees, and there were numerous Assiminea brevicula on the mud at their bases.

As usual, several species were associated with the dead stumps: Murex, Nerita, Cerithidea, Littorina.

At this locality half the Murex and Cerithidea shells were filled with hermit crabs. No living Ellobium was found. As before, Engina was found in a shallow drainage stream.

Station 12. The only living vegetation was a vast field of Paspalum. There were huge stumps of Avicennia and Xylocarpus. Numerous dead Murex were filled with crabs.

Associated with the grass were Assiminea brevicula, Cerithidea alata, Melampus siamensis, and the two species of Laemodonta.

Station 13. This was a managed mangrove of Avicennia officinalis. On the trees were found Littorina scabra and L. melanostoma, Nerita, Murex, and a large black Onchidium (30 to 40 mm long). On the substrate were found Assiminea brevicula, another species of Onchidium, and Cassidula faba.

Very narrow and shallow drainage streams supported two species of Iravadia, and Stenothyra monilifera. Deeper streams yielded Nassarius and Engina. Diked pools near the road were filled with thousands of Cerithidea cingulata.

Station 14. We made a transect from the river to dry land at this point in Chi-Linh, a distance of about one-quarter of a mile (400 m). The dry land was a dune surmounted by Hong-Linh Hill. We collected in the area adjacent to the control plot sprayed by helicopter.

On the river bank were Avicennia officinalis and many Rhizophora apiculata. This zone yielded numerous Assiminea brevicula and Cerithidea obtusa on the mud. Littorina was found on the trees (trunk and leaves) up to 7 ft (2.1 m). The large black Onchidium of Station 13 was present on trees.

In from the river bank some 100 ft (30 m) was a mixture of Rhizophora and Ceriops. Littorina was found in the trees. Cassidula nuclea and C. aurisfelis appeared on the mud and 1 ft (0.3 m) up into the trees. Assiminea and Dostia were on the mud; Nerita was on the mud and in the trees up to 2 ft (0.6 m). Cerithidea was on the mud and in trees up to 4 ft (1.2 m) (very abundant on Ceriops).

Lateral to Station 14 were two plots, hand cleared and sprayed by Professor Blackman and Dr. Lang (Committee member and Chairman, respectively). One micro-plot was sprayed with Agent Orange, the other with Agent White. Subsequently, Rhizophora and Ceriops seedlings were planted some 3 and 6 weeks after spraying. Almost all survived. When the young plants were 1.5 ft (0.5 m) tall Littorina melanostoma was found on them. Living Cerithidea obtusa and Assiminea brevicula were seen on the soil.

Station 15. Ceriops and Xylocarpus surrounded a stream and pond. The pond had a salinity of 35.3 ‰. In this very saline water were found two species of Stenothyra, Fairbankia, Iravadia reticulata, and Amphibola. The Fairbankia and Iravadia were located on the underside of leaves in the shallow water. The Stenothyra plowed the surface of the mud.

Station 16. A dry environment at the edge of the mangrove at Hong-Linh Hill under Phoenix bushes yielded a few specimens of Ellobium aurisjudae (immature), Phytia trigona, and Littorina scabra.

Station 17. A transect was made between the sand dunes and the river. The dry areas under Phoenix plants yielded only one Ellobium aurisjudae. Halfway to the river the trees were mostly Rhizophora with one large Avicennia tree. On this large tree were Cassidula aurisfelis, Cerithidea, and large Ellobium aurisjudae in the rotting wood in a notch of the tree.

In the low lands near the river were thousands of Cerithidea among the Rhizophora.

Stations 18 to 20. These stations were along the road from the sand dunes, across the river, to route QL 15, which runs the length of the Vung-Tau Peninsula. They ranged from the edge of the river to the dry northwestern fringe of the mangrove.

Station 18 was dominated by Rhizophora apiculata. There were some Ceriops, Avicennia, and very few Xylocarpus. The two Littorina were common on the trees. The large black Onchidium was found on tree trunks to a height of 3 m, especially on dead wood. Cerithidea obtusa and Murex were abundant about the base of trees. Assiminea brevicula was common on the surface of the exposed mud along with Amphibola. Murex was found feeding on Cerithidea quadrata and Nerita.

The two species of Stenothyra were abundant on the mud in small drainage streams.

In the main drainage stream, 6 to 8 in. (15-20 cm) deep at low tide, were thousands of Cerithidea, especially C. angulata and C. alata. Murex was preying upon them.

Station 19 was an Excoecaria association with some Ceriops and Xylocarpus.

A large stream (permanent flow at low tide, about 20 ft wide, 1 or

more ft deep) flowed through this station. In the stream were Cerithidea cingulata and C. alata. Rapid water running down from a road-bearing culvert yielded numerous Iravadia reticulata clinging to the underside of rocks.

On plants and the mud (exposed at low tides, not necessarily flooded by every high tide) were Ellobium aurisjudae, Cassidula aurisfelis, and C. nuclea. Also, Cerithidea obtusa and Assiminea brevicula were common.

There were few Littorina scabra and a few Onchidium sp.

Station 20 was at the dry edge of the mangrove, the Lumnitzera zone. There were some Ceriops sp., a few Excoecaria, and Phoenix. Snails are abundant here probably only during the rainy season. A few dead shells of Melampus siamensis were found.

Summary of Habitat Associations

1. Arboreal. Littorina scabra was found high in the trees both on the bark and on the leaves, to a height of 25 ft (7.5 m). Littorina melanostoma likewise was observed on trees.

The large black Onchidium sp. of Chi-Linh was prominent on dead tree trunks, both standing and fallen.

Nerita, Cerithidea obtusa, and C. quadrata were found to a height of 3 or 4 ft (0.9-1.2 m) on living trees.

Ellobium aurisjudae was found associated with rotting wood, either on the ground or in stumps, notches, or holes in trees, to a height of 4 ft (1.2 m).

Murex occasionally was found up to 2 ft (0.6 m) above the mud.

2. Paspalum grass. Littorina melanostoma was found clinging to the stems of the grass. On the mud beneath were Assiminea brevicula, Laemodonta punctatostriata and L. punctigera, Melampus siamensis.

3. Exposed mud surfaces. Assiminea brevicula was common along with Amphibola (in Chi-Linh) and some small ellobiids such as Laemodonta (not numerous in this environment). Polymesoda was found here also.

4. Rotting wood, piles of wood trash, dry areas beneath plants such as Acrostichum and Phoenix. Ellobiids such as Ellobium, Phytia, and Cassidula were found in these locations.

5. Mud surfaces, under water in small drainage streams. Common in 2-4 in. of water were Stenothyra, Fairbankia, Iravadia. Also found were Engina and Nassarius. Common to pools or deeper streams (6-12 in.) were Cerithidea cingulata and C. alata.

6. Mud surfaces at the base of trees. Murex, Nerita, Dostia, Cerithidea obtusa, C. quadrata, Haminoea, Assiminea appeared in these vicinities.

7. Nypa plants. Enigmonia was found on the fronds and Neritodryas at the base of the plant. Dostia was found here and some areas yielded a few Cerithidea obtusa.

DISCUSSION

Literature and Nomenclatural Adjustments

Prominent papers dealing with mangroves or molluscan faunas of

mangroves are those of Macnae (1968), Berry (1964), and Brown (1971). Of particular help are the papers of Van Benthem Jutting, especially her 1956 paper. The unpublished thesis of Cuong (1964) is of critical importance to the Saigon-Vung-Tau region.

Nerita birmanica Phil. of the literature is a synonym for Nerita lineata. The Nerita of this study corresponds exactly to the concept of N. birmanica intended by Macnae and others for Malaya.

Cassidula mustellina (Dech.) is considered a synonym of C. nuclea. The material corresponds to the mustellina of authors for Malaya-Thailand mangroves.

Enigmonia rosea (Gray) is a color variant of Enigmonia aenigmatica of this report.

Dostia crepidularia of the literature is a synonym for Dostia violacea.

The Molluscan Diversity

Brown (1971), in his studies of a South African mangrove swamp, found 12 species of gastropod while Berry (1964) listed 17 species from Malayan mangroves. This report discusses 40 species, representing an amazingly diverse assemblage of organisms.

The ancient Neritacea is represented along with gill-breathing mesogastropods of diverse anatomy and ecological requirements such as the Assimineidae, Littorinidae, Stenothyridae, Iravadiidae, Lacunidae. More primitive mesogastropods are represented by seven species of the cerithiacean family Potamididae. More recently evolved predators such

as Murex, Engina, and Nassarius complete the gill-breathing group, i.e., Prosobranchia, Neogastropoda.

More highly evolved yet are the lung-breathing pulmonates with their comparatively primitive families (for pulmonates) Ellobiidae and Amphibolidae. In the mangroves the ellobiids have reached their greatest diversity in ecological niches and genetic divergence. The family has 11 distinct representatives in the Saigon-Vung-Tau mangroves that inhabit both the dry landward fringe and areas inundated twice every day.

Highly evolved and specialized is the opisthobranch order Onchidiacea.

Taken as a group, these species exhibit a wide range of habitats and food procuring processes. They present diverse forms of "generalized" and "specialized" organisms, in terms of flexibility to withstand environmental change or inflexibility to environmental trauma.

Reproductive habits have much to do with potential to reinvade an environment devastated by any type of disaster. Some species bear young alive, some lay eggs which undergo direct development, and yet others lay eggs which yield a free-swimming veliger stage. Littorina scabra is ovoviviparous. While there are no data, it is suspected that L. melanostoma is likewise ovoviviparous (Rosewater 1970). The breeding habits, spawn, and developmental sequence is mostly unknown for the fauna discussed here. A great percentage, however, have veliger larvae.

Effects of Defoliation and Recovery

Since there is no prior experimental evidence concerning the

molluscicidal effects of Agents Orange and White, the one assumption made here is that the intensive defoliation program destroyed all molluscan individuals where trees were killed. It is obvious that here and there groves or individual trees survived the defoliation sprays and that some of the associated mollusks survived.

Evidently, the species most able to tolerate the direct heat of the sun on the mudflats and obtain food are species such as Nerita, Murex, Assiminea brevicula, Littorina scabra, Cerithidea quadrata, and C. obtusa.

With increased vegetation and shade the numbers of species and quantity of any one species increases, e.g., the association of Littorina melanostoma on Paspalum grass and Laemondonta on the mud throughout the grass. The richer finds of Nerita, Cerithidea obtusa, and Littorina scabra are on or under large living trees.

Accordingly, the molluscan species recorded alive from the Rung-Sat are considered primary colonizers. The deformities of shell, which would reflect an adverse effect of the defoliating agents, were not seen in the individuals collected. The Littorina collected were half-sized, reflecting a colonization period of perhaps a year. Future studies would reveal if the small size is truly owing to a young age, or if the organisms have been stunted by a restricted non-optional environment or chemical effects.

Murex individuals were numerous, full-sized, and normal. As predators they occupy the top of the food chain with regard to mollusks. They prey especially on bivalves and Nerita, and their large numbers indicate that an adequate food source is available to support them. This is a very healthy sign.

The abundance of dead Murex and Polymesoda shells is ample evidence of the destructive effects of the defoliation agents. While Murex populations have recovered to a normal level this cannot be said of the clam Polymesoda. A few very large live clams were collected, indicating that there was some survival. However, no living young clams were collected. This may be a collection oversight, but is rather taken to indicate a very slow recovery of this species relative to Murex. A future study should concentrate on this species, to determine if the defoliating agents had a serious effect on the reproduction and development of Polymesoda (Geolina) coaxans.

At several sites deep in the Rung-Sat there were numerous dead Ellobium shells. In every such site, however, large healthy living specimens were collected from decaying wood or from under piles of plant trash. Ellobium and Phytia populations are recovering well.

In flying from Saigon to Vung-Tau at low altitudes over the Rung-Sat it is evident that plant life is coming back. This is especially noticeable along the edges of the rivers and streams flowing into the main rivers traversing the Rung-Sat. While thousands of acres are yet barren, plants are springing up in numerous localities. With increased plant life comes an increased molluscan fauna.

The evidence at hand shows a progressive recovery of the flora and fauna. Sensitive species such as those in the genera Stenothyra, Fairbankia, Iravadia, and Amphibola should return to the Rung-Sat with the advent of greater foliage cover, although it may be 8 to 10 years before this stage is reached. Species of these genera should be able to thrive in large areas of the Rung-Sat.

It is not known how much the close proximity of the sea affects the occurrence of Cerithidea, Batillaria, and Cassidula found only at Chi-Linh. Several of these species may never have been inhabitants of the central portions of the Rung-Sat.

Limitations of this Report

Data presented here were collected from too few stations and under pressing conditions of security. It is possible that species recorded only from Chi-Linh may be found elsewhere in the Rung Sat. Likewise, it is predicted that the Haminoea recorded only from the Rung-Sat could be found at Chi-Linh. Considering the limited data available, and the lack of information on conditions prior to the defoliation program, it is wise to avoid too great an amount of speculation.

However, the Rung-Sat-Vung-Tau mangroves have more fauna than is recorded from mangroves elsewhere. Those species that should occur in the region, do. No species appears to have been destroyed locally or made extinct. It is not difficult to predict a normal recovery of the Rung-Sat with respect to a normal molluscan fauna. The one possible exception involves the recovery of Polymesoda (Geolina) coaxans. Only intensive collections and studies of this species can answer the question about Polymesoda.

Despite the lack of quantitative data, this report does serve as a baseline for general conditions of flora and fauna in the Rung-Sat-Vung-Tau region. Future studies should be undertaken.

RECOMMENDATIONS FOR FUTURE STUDIES

1. It is recommended that in 1975 a thorough qualitative and

quantitative analysis of the molluscan fauna be made at the same stations in the Rung-Sat and at Vung-Tau as were sampled in this report so that the trends predicted here may be assessed. The degree of plant recovery should likewise be made both qualitatively and quantitatively. Attention should be given to the height of the plants, the species, and numbers per unit area. The analysis of the molluscan fauna should be made with regard to the plant associations in the same quadrats.

At that time at least 10 additional localities should be established both in the Rung-Sat and in a different area at Chi-Linh. Another control mangrove should be found and studied, especially in an undisturbed area such as Thailand. Additional sites may lessen the chance that a species found only once or in very sparse numbers in this study be considered rare.

More time should be spent at each station so that collections farther from the river could be made, and the areas could be sampled more thoroughly. Mollusks as sensitive indicators of environmental quality would indicate the rate of mangrove recovery along with mangrove plant species, their rates of seeding-in and growth.

2. A study of Polymesoda coaxans should be made to determine the actual status of this species in the Rung-Sat. There is some evidence that this species was hard hit by the defoliants and is not recovering at a healthy rate. Attention should be given to reproductive processes and growth rates in control areas and in the Rung-Sat. Analysis of P. coaxans tissues from the Rung-Sat should be made to determine if a chemical residue has accumulated in the clam; likewise a histological

study should be made of oogenesis and spermatogenesis of those individuals in the Rung-Sat that survived the spraying.

3. Populations of Iravadia, Fairbankia, Assiminea, Phytia, Cassidula, Laemodonta, Cerithidea, Littorina, and Stenothyra should be studied anatomically, histologically, and cytologically to determine if there are genetic defects resulting from the severe herbicidal treatment of the Rung-Sat. Histology of the gonad and cytological analysis of the chromosomes would reveal gross detrimental effects on the germ cells should these occur. Anatomical data on the head-foot region, and nervous and reproductive systems would reveal any induced deformation.

The families mentioned above are included because they represent a diversity in evolutionary history, morphological types, and sensitivity to detrimental environmental conditions. They are highly representative of the mangrove fauna.

4. The rate of plant invasion and growth should be monitored for key selected species.

Commercial Aspects and the Future

It should be mentioned that Cerithidea obtusa is sold for food in the market and is considered delicious. This species is an economic asset and has made an excellent recovery in the Rung-Sat. No abnormal individuals were noted.

The areas dominated by Cyperus are prime areas for development of rice culture. This should be considered for the northern fringes of the Rung-Sat.

The central areas, now vast mud flats, could be turned into an economic asset if sections were structured as managed mangroves like the one at Station 13. In the years to come there will be increasing demands for mangrove wood as a source of energy. At this stage in mangrove recovery it would be very possible to reforest and manage the area to the best possible advantage.

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