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Item ID Number	03837	☐ **Not Scanned**
Author	De Sylva, Donald P.	
Corporate Author	University of Miami, Rosenstiel School of Marine and At	
Report/Article Title	The Effects of Herbicides in South Vietnam: Part B, Working Papers, February 1974: Effects of Mangrove Defoliation on the Estuarine Ecology and Fisheries of South Vietnam	
Journal/Book Title		
Year	1974	
Month/Day	February	
Color	☐	
Number of Images	128	
Descripton Notes	AD-779 014. Contribution No. 1702. Last three pages are duplicated.	

JML $4.75

AD-779 014

THE EFFECTS OF HERBICIDES IN SOUTH VIETNAM

PART B. WORKING PAPERS: EFFECTS OF MANGROVE DEFOLIATION ON THE ESTUARINE ECOLOGY AND FISHERIES OF SOUTH VIETNAM

NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL

FEBRUARY 1974

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PART B: WORKING PAPERS

FEBRUARY 1974

Effects of Mangrove Defoliation on the Estuarine Ecology and Fisheries of South Vietnam

DONALD P. DE SYLVA AND HARDING B. MICHEL

NATIONAL ACADEMY OF SCIENCES - NATIONAL RESEARCH COUNCIL

WASHINGTON, D.C. 20418

Effects of Mangrove Defoliation on the Estuarine Ecology and Fisheries of South Vietnam[a]

DONALD P. DE SYLVA AND HARDING B. MICHEL[b]

Mangroves are an intrinsic part of the tropical coastal and estuarine environment (Lauff 1967). Although some species are restricted to land, a large part of the mangrove ecosystem comprises aquatic habitats characterized by the ebb and flow of tidal salt water (Macnae 1968). The complex aerial root system acts as substrate for the attachment of various invertebrate organisms such as worms, snails, oysters, mussels, and barnacles (Berry 1964). Beneath the water and submerged among the labyrinth of roots, the young stages of fishes, crabs, and shrimps find food and shelter from predators. Thus, the mangroves act as nursery grounds for a variety of aquatic organisms (Fischer-Piette 1931).

The root complex of mangroves also serves as a sediment trap to keep soil from eroding (Stephens 1963), and silt-laden water flowing across mangroves is filtered by the roots (Gledhill 1963, Gigliogli and Thornton 1965). The result is that the water becomes clearer (Tabb et al. 1962), permitting greater light penetration, and therefore photosynthesis, to occur at levels deeper in the water column than would be possible in turbid water. Hence, production of aquatic organisms is indirectly increased by mangroves (Davis 1940), which are among the most fertile ecosystems (Golley et al. 1962).

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Recently it has been found that the great worth of mangroves to the aquatic ecosystem is through the contribution of decaying leaves to the food chain in the aquatic environment (Heald 1971, Odum 1970, Odum and Heald 1972). As the leaves decompose in the water, they are changed biochemically by fungi into protein for various kinds of benthos and plankton. This organic debris amounts to approximately 3 tons/acre of potential food for plankton and benthos. The organic contribution from decomposing mangrove seedlings may be even greater. The food thus produced by fungi from these leaves is eaten by shrimps, crabs, worms, roundworms, and snails, as well as by several hundred different kinds of organisms in the plankton (Fell and Master 1973). In turn, these consumers are a primary source of food for tropical commerical fishes such as flounders, herrings, mullets, porgies, jacks, anchovies, snappers, and croakers (Freise 1935). Thus, destruction of mangroves reduces both food and shelter for important fishes, as well as invertebrates such as crabs and shrimps (Freyberg 1930).

On the basis of the above concepts, scientists have suggested that the destruction of large parts of the estuarine and coastal mangrove forests of South Vietnam (SVN) through military defoliation (Tschirley 1969, Odum 1971) should affect the life cycles of fishes dependent upon this region (Orians and Pfeiffer 1970, Erlich and Erlich 1972). Further, they expect a decrease in the commerical fishery for aquatic species that depend on the mangroves for food, shelter, or spawning grounds (Gerlach 1958, Kiener 1966, Walsh 1967, de Sylva 1970). Herbicides used for defoliation may have affected the fishes and invertebrates of the mangrove region either by killing them outright or by interfering, sublethally, with normal physiological processes such as feeding, reproduction, behavior, and migratory patterns. Finally, it has been theorized (Meselson et al. 1970) that the herbicides--including their breakdown products, or contaminants accidentally produced during their manufacture--may have been passed on through the food chain by way of decaying mangrove leaves, and subsequently into water and sediments, plankton, intermediate-size predators, and thence finally into large fishes and invertebrates of commerical value which are so important in the Vietnamese diet. One such contaminant--dioxin--has been found in fish and shrimp taken near defoliated areas (Shapley 1973).

It was the purpose of this study, then, to attempt to evaluate some of the above factors by collecting data in the defoliated mangrove forest of SVN (Figures 1 and 2) and to compare ecological information with data from a mangrove region that had not been sprayed with herbicides (control region). Positions for collecting stations for studies made in the defoliated and nondefoliated areas are given in Table I.

The original intent was to select a control area in the Ca-Mau Peninsula, which has been relatively untouched by military defoliants, and which is distant from large urban populations or other sources of pollution. Security restrictions prevented us from entering this region, and a less desirable control area (subsequently referred to as the Vung-Tau Region) was necessarily selected. However, the Vung-Tau Region, even though it was the least sprayed mangrove area available to us, nevertheless had been subjected to herbicidal spraying in two contiguous regions in Phuoc-Tuy Province (Table II; Figures 3 and 4, Targets 1 and 2)

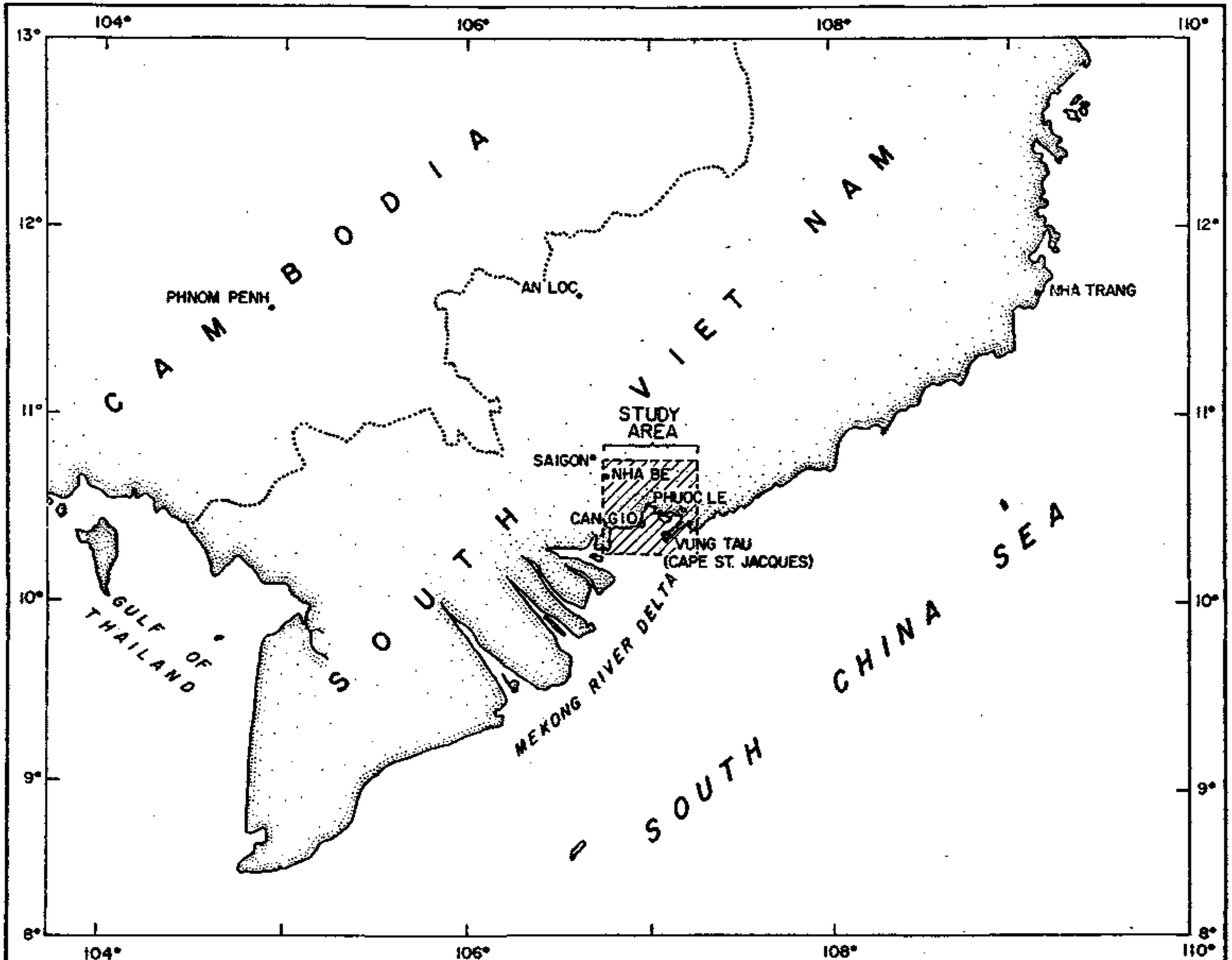

FIG. 1. Location of studies on the estuarine ecology and fisheries of SVN.

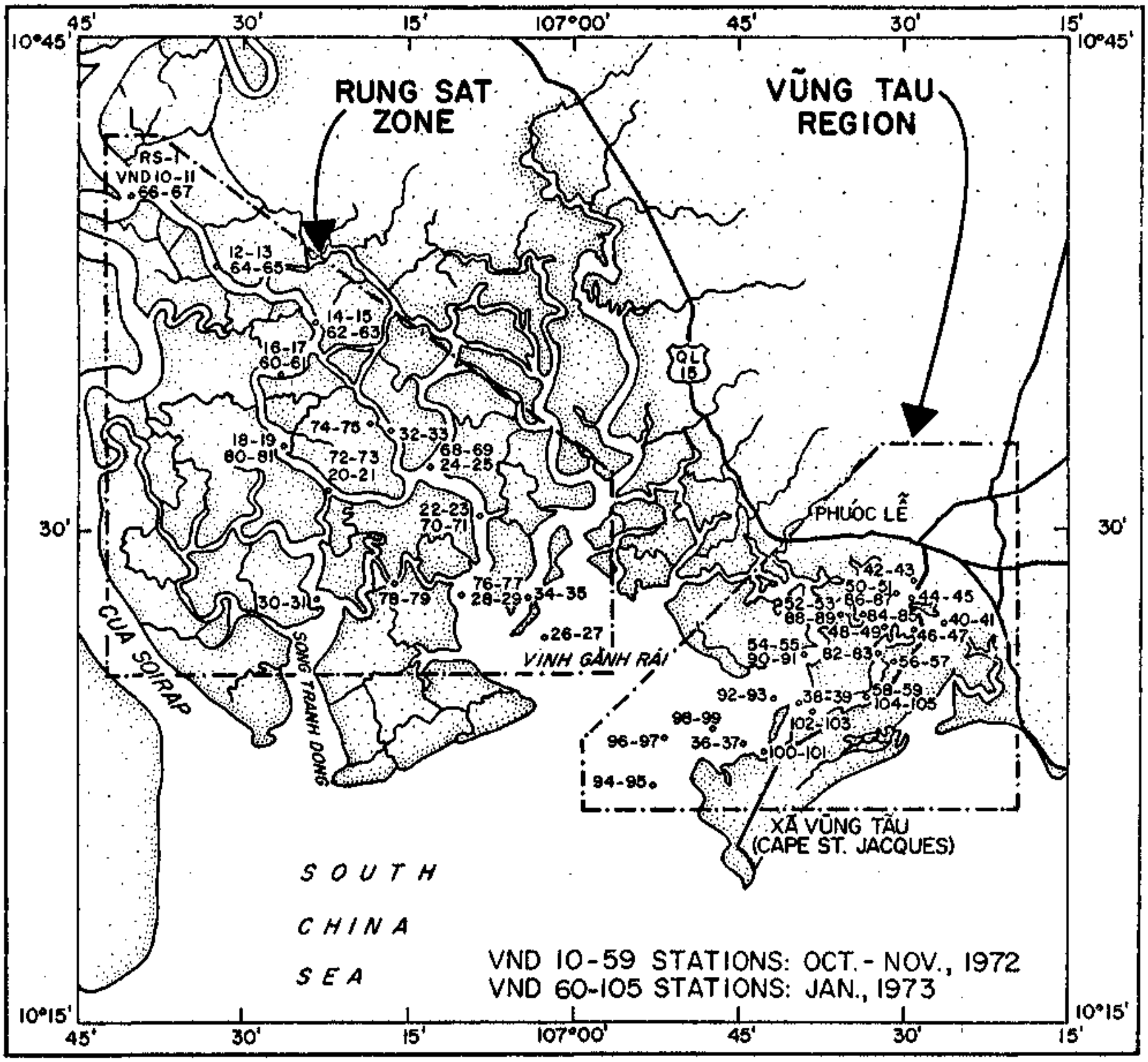

FIG. 2. Location of collecting stations in the Rung-Sat Special Zone and the Vung-Tau Region, SVN, 1972 and 1973.

Table I.

Location of collecting stations (VND) in the Rung-Sat Special Zone and Vung-Tau Region, SVN, October-November 1972 and January 1973.

Station	Latitude	Longitude		Station	Latitude	Longitude	
VND 10-11 = VND 66-67	10°40'06"N	106°46'38"E	Rung Sat	VND 40-41	10°27'09"N	107°11'08"E	Vung Tau
VND 12-13 = VND 64-65	10°38'05"N	106°49'00"E	Rung Sat	VND 42-43	10°28'24"N	107°10'13"E	Vung Tau
VND 14-15 = VND 62-63	10°36'34"N	106°52'02"E	Rung Sat	VND 44-45	10°27'55"N	107°10'15"E	Vung Tau
VND 16-17 = VND 60-61	10°34'50"N	106°50'46"E	Rung Sat	VND 46-47	10°27'14"N	107°10'19"E	Vung Tau
VND 18-19 = VND 80-81	10°32'25"N	106°50'59"E	Rung Sat	VND 48-49	10°27'17"N	107°09'35"E	Vung Tau
VND 20-21 = VND 72-73	10°31'22"N	106°52'32"E	Rung Sat	VND 50-51 = VND 86-87	10°27'30"N	107°08'49"E	Vung Tau
VND 22-23 = VND 70-71	10°30'40"N	106°57'17"E	Rung Sat	VND 52-53 = VND 88-89	10°27'18"N	107°07'58"E	Vung Tau
VND 24-25 = VND 68-69	10°31'50"N	106°55'11"E	Rung Sat	VND 54-55 = VND 90-91	10°26'12"N	107°07'00"E	Vung Tau
VND 26-27	10°26'47"N	106°59'13"E	Rung Sat	VND 56-57	10°26'00"N	107°09'47"E	Vung Tau
VND 28-29 = VND 76-77	10°28'10"N	106°56'35"E	Rung Sat	VND 58-59 = VND 104-105	10°24'52"N	107°08'54"E	Vung Tau
VND 30-31	10°28'00"N	106°52'20"E	Rung Sat	VND 82-83	10°26'17"N	107°09'15"E	Vung Tau
VND 32-33 = VND 74-75	10°33'30"N	106°54'05"E	Rung Sat	VND 84-85	10°27'51"N	107°09'36"E	Vung Tau
VND 34-35	10°27'53"N	106°58'26"E	Rung Sat	VND 92-93	10°24'49"N	107°05'45"E	Vung Tau
VND 78-79	10°28'20"N	106°54'40"E	Rung Sat	VND 94-95	10°22'50"N	107°02'41"E	Vung Tau
VND 36-37 = VND 98-99	10°23'54"N	107°04'10"E	Vung Tau	VND 96-97	10°23'15"N	107°03'28"E	Vung Tau
VND 38-39 = VND 102-103	10°24'31"N	107°06'53"E	Vung Tau	VND 100-101	10°23'34"N	107°05'20"E	Vung Tau

Table II.

Spray missions in Phuoc-Tuy Province (near Vung-Tau), 1962-1968. Data from the List of 202 Task Realized file and HERBS tape.

YEAR	AGENT IN GALLONS			
	PURPLE	ORANGE	WHITE	TOTAL
Target 1 (and vicinity)				
1962	4,000[a]	--	--	4,000[a]
1964	--	14,000	--	14,000
1965	--	5,000	--	5,000
1966	--	21,650	--	21,650
1967	--	16,200	6,100	22,300
1968	--	11,675	45,000	56,675
TOTAL	4,000[a]	68,525	51,100	123,625
Target 2				
1965	--	6,000	--	6,000
1966	--	21,600	--	21,600
1968	--	--	7,000	7,000
TOTAL	--	27,600	7,000	34,600
Target 3				
1965	--	8,850	--	8,850
1966	--	5,150	--	5,150
1967	--	23,740	--	23,740
1968	--	20,650	29,400	50,050
TOTAL	--	58,390	29,400	87,790

[a] Test spraying along Route 15.

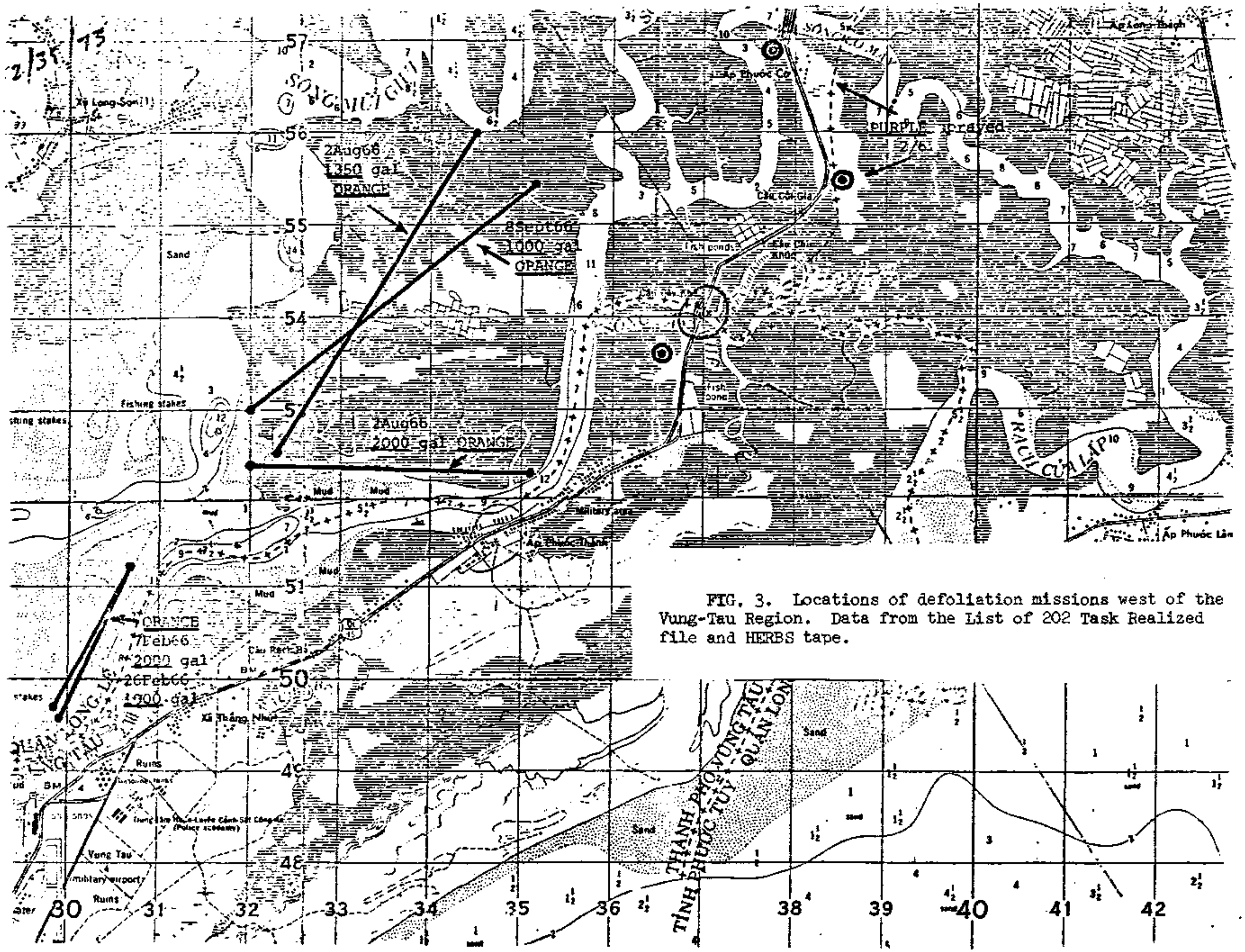

FIG. 3. Locations of defoliation missions west of the Vung-Tau Region. Data from the List of 202 Task Realized file and HERBS tape.

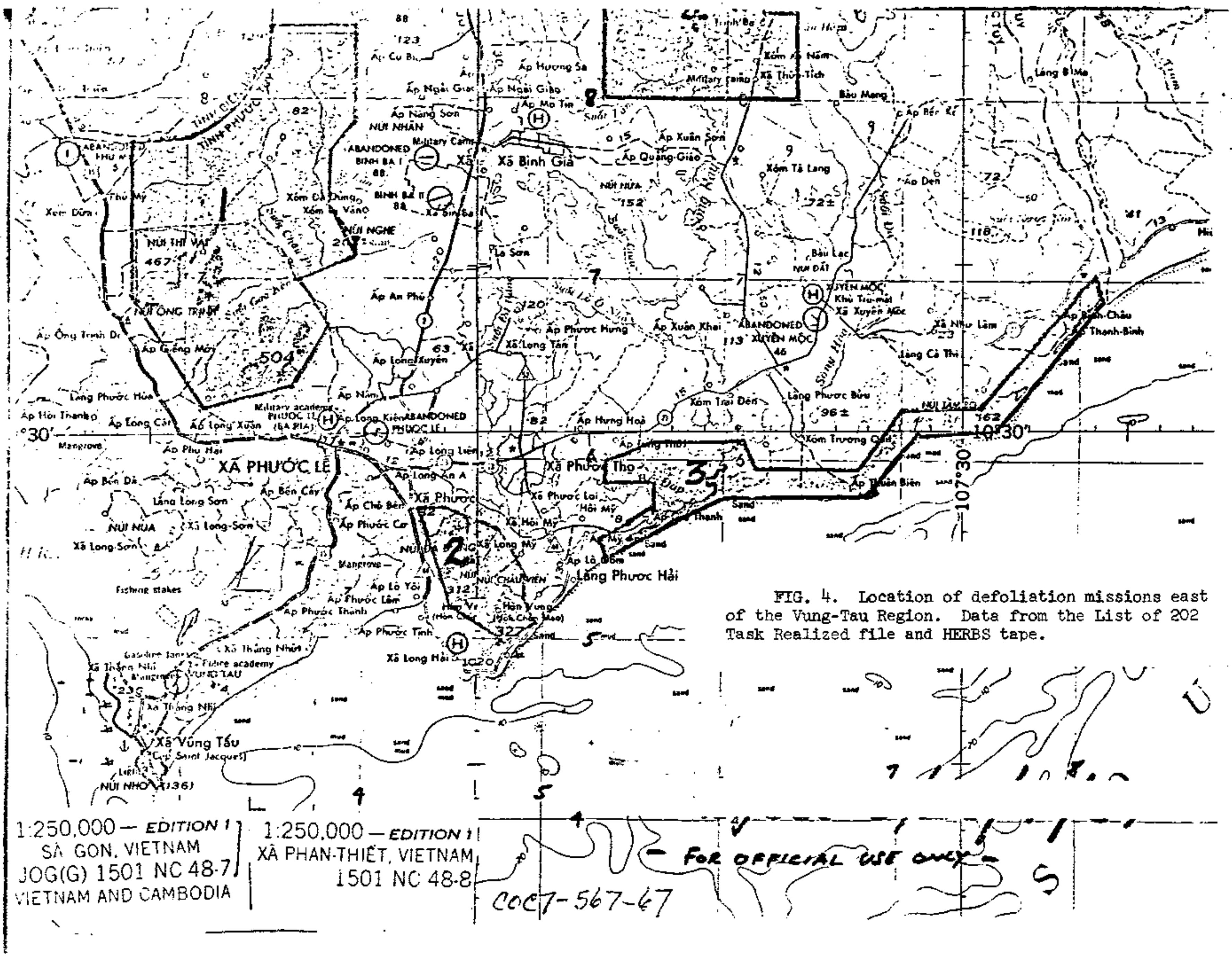

FIG. 4. Location of defoliation missions east of the Vung-Tau Region. Data from the List of 202 Task Realized file and HERBS tape.

as recently as 1968. The defoliating agents used were Orange (2,4-D and 2,4,5-T), Purple (same as Orange, with slight molecular variation), and White (2,4-D and picloram), totalling about 158,000 gal sprayed adjacent to the Vung-Tau Region (Table II). In comparison, the heavily defoliated Rung-Sat Special Zone received direct application of over 1.1 million gal of spray during a comparable period (Table III). Target areas 1 and 2 comprise hilly areas, and during the rainy season it would be expected that any residual herbicides, contaminants, or breakdown products from these targets could be carried into the mangrove estuary of the Vung-Tau Region. Another factor is that the two areas are not strictly comparable in their soils, muds, and tidal characteristics, as will be discussed.

Limitations of Study

A number of factors clearly limit the conclusions that can be drawn based upon the present study. Chief among these is the lack of almost any qualitative or quantitative background data both in the defoliated area and the control region. Nearly all aquatic studies in Indochina seem to have been confined to open waters or inland streams and ponds (Soulier 1963, de Sylva 1973a); virtually nothing is known about the estuarine ecology of mangroves in SVN or the organisms inhabiting these regions. Some conclusions may be inferred based on the kinds of animals living there, by using studies following the defoliation, and comparing them with what is known about similar mangrove habitats in Malaysia, Africa, or the Caribbean, because usually the same families of animals inhabit the same kinds of mangrove communities. However, hypothetical data cannot be extrapolated on the numbers of aquatic animals

Table III.

Defoliation missions in the Rung-Sat Special Zone. Data from the List of 202 Task Realized file and HERBS tape.

	Orange		White		Blue	
Year	Missions	Gallons	Missions	Gallons	Missions	Gallons
1964	--	31,650[a]	--	--	--	--
1965	--	27,000[b]	--	--	--	--
1966	32	74,900	5	16,625	3	8,100
1967	89	315,200	17	46,235	4	13,500
1968	39	161,850	66	245,325	10	27,500
1969	22	101,300	4	26,200	--	--
1970	5	12,400	3	9,000	--	--
Total	187	724,300	95	343,385	17	49,100

[a]From List of 202 Task Realized File

[b]From HERBS tape

living in Vietnam prior to mangrove defoliation. Thus, we really do not know what kinds or how many organisms were there before wartime conditions prevailed. Large-scale defoliation or other alteration of an environment would be expected to produce widespread changes in the kinds of animals and plants because the physical environment is changed with resultant ecological succession. Thus, even though many animals were found, they might not be ecologically desirable or valuable to the ecosystem represented by the mangrove community (de Sylva 1972).

Another problem confronting us is that defoliation flights ceased two years prior to our study. Although defoliation may have had severe immediate effects, and even though the mangroves themselves have still not regenerated substantially (as of 1973), perhaps any damage to the aquatic habitat and its organisms may not have been permanent. Thus we might be studying an environment that is actually recovering rather than one that has been damaged permanently. Of course, one of the goals of this study has indeed been to determine if any ecological damage is permanent or temporary.

Because collections were made under wartime conditions, it was frequently impossible to collect in areas because of security restrictions imposed by military activity. In some instances, collecting stations could not be repeated in the same area, and hence comparable data were unobtainable. It was also impossible to make nighttime collections because of security reasons. Many aquatic organisms burrow into the mud during the day, so that they cannot be easily caught with nets, and thus they must be captured at night. Further, we were restricted to the use of a small bottom trawl for the capture of fishes and invertebrates. Larger and more varied types of nets, traps, seines, gill nets, and weirs undoubtedly would have yielded a more representative sample of the fishes of the mangrove ecosystem, but these could not be used for logistic and security reasons. Also, larval fishes and plankton migrate to, and are more numerous at, the surface (where our collections necessarily were made) during the night than they are during the day. Under ideal conditions, then, collections would be made both during night and day.

Of course, the obvious limitation of our study is its short-term nature. Statistical chance dictates that with the spot sampling necessitated by security problems, data will be limited at best.

In the control area, South Vietnamese naval personnel routinely dropped hand grenades into the water to discourage enemy underwater demolition experts (UDT's) or to detonate mines suspected of being planted by enemy UDT's. Hence, the "control area" we selected could not really be considered as being one untouched by human activity.

In both the defoliated Rung-Sat Special Zone and the nondefoliated Vung-Tau Region, the extensive river traffic from large vessels and military patrol craft adds greatly to the already turbid condition of the water by stirring up the bottom with propellers and by causing erosion of the stream banks from boat wakes. Resulting siltation and turbidity can reduce productivity in both areas, reducing light penetration and therefore photosynthetic activity of aquatic planktonic and benthonic plants.

Finally, the effects of mangrove defoliation upon the aquatic organisms cannot be separated from other kinds of environmental degradation

(Orians and Pfeiffer 1970). Chlorinated hydrocarbons have been sprayed to control various insect pests throughout Indochina since the end of World War II, and, more recently, organophosphates such as malathion have been added to the list of pesticides. Sewage from the Saigon area and, to a lesser extent, industrial wastes, accidental spills of oil and other hydrocarbons, and a host of unknown war-related materiel contaminate the waters flowing through the Rung-Sat Special Zone. The deleterious effects upon the aquatic ecosystem of any pollutant by itself or through its synergistic effect with other pollutants (including defoliants) can only be speculated upon pending necessary laboratory and field studies.

METHODS AND MATERIALS

The primary area of mangrove defoliation in SVN is the Rung-Sat Special Zone (Figure 1), once a region thickly covered by several species of mangrove trees, including Rhizophora, Avicennia, Sonneratia, Bruguiera, and Ceriops. The aquatic environment here is typified by tortuous, deep channels characterized by tidal velocities that may exceed 3 knots (Kopenski 1968). Extensive tidal mixing and stirring occurs (Figure 5), so that the waters are continuously turbid (Table IV). Salt water moves upstream near the river bottom as far as the town of Nha-Be. Above this is a layer of freshwater runoff at all tidal stages that is detectable throughout the Rung-Sat Special Zone.

The control region (the Vung-Tau Region) comprises the Song-Co-May and Song-Mui-Giui (rivers); it is subject to relatively weaker tidal currents (estimated at 1 to 2 knots, maximum) than in the Rung-Sat, and has

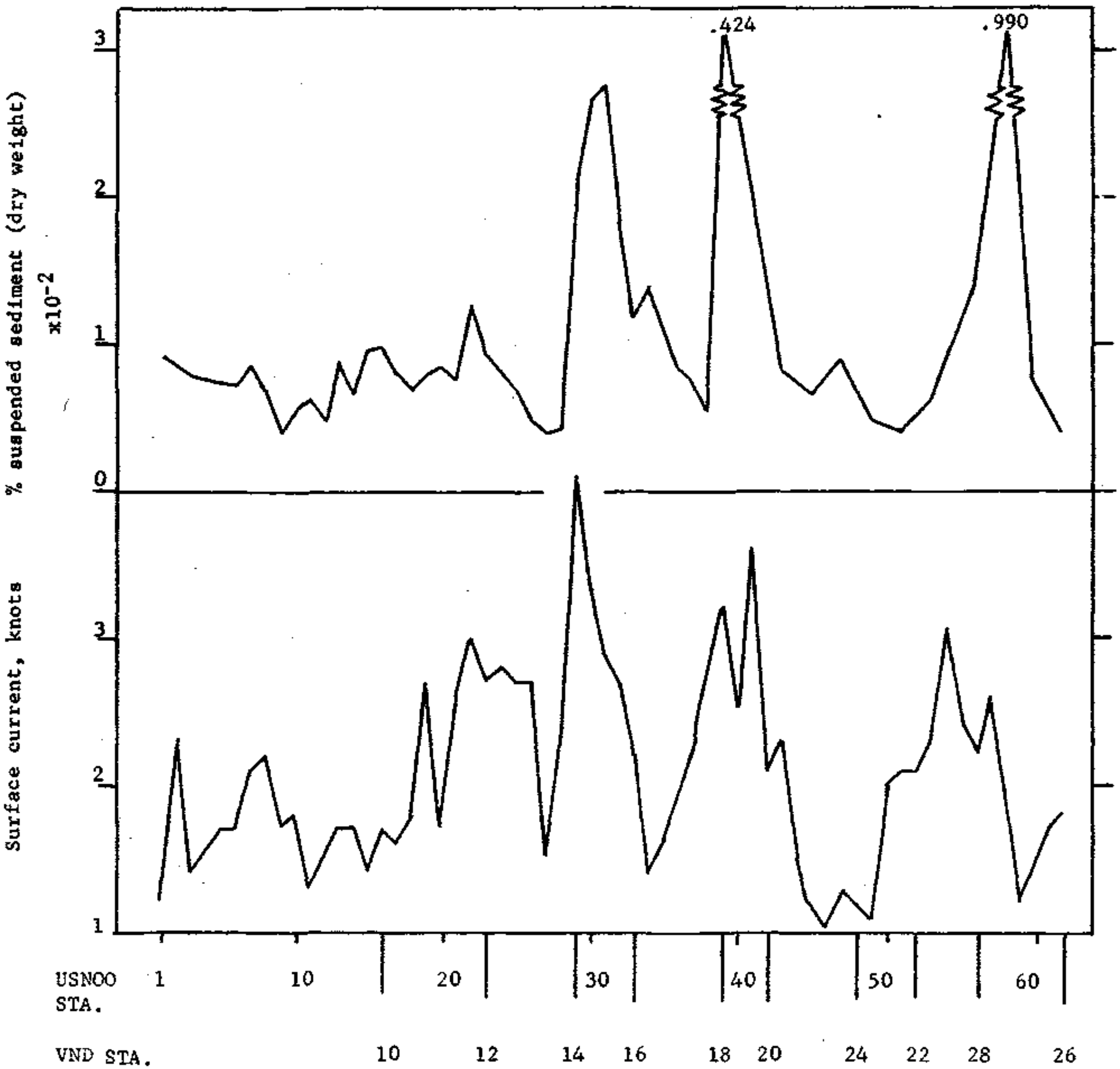

FIG. 5. Sediment load (% by wt) and current speed (knots) observed in the Saigon, Nha-Be, and Long-Tau Rivers, SVN, Sept. 3-10, 1967, at various tidal stages. U.S. Naval Oceanographic Office data (Kopenski 1968). All VND stations are in the defoliated Rung-Sat Special Zone.

Table IV.

Summary of hydrographic and biological data collected in mangrove region of SVN, 1972-73. The Rung-Sat Special Zone is defoliated; Vung-Tau is nondefoliated (control region). Wet-season collections were made in October and November 1972. Dry-season collections were made in January 1973.

	Rung-Sat wet	Rung-Sat dry	Vung-Tau wet	Vung-Tau dry
Average values for each area				
Temperature, °C	28.8	27.4	29.5	26.8
Oxygen, ppm	4.1	4.4	5.6	6.4
Oxygen saturation, %	67	67	90	98
Salinity, $^{o}/oo$	11.5	17.0	27.8	30.7
pH	7.5	7.4	8.0	7.9
Turbidity, JTU	62	55	8	4
Number of organisms				
Copepods	127×10^3	117×10^3	273×10^3	114×10^3
Diatoms	106×10^4	456×10^2	511×10^4	229×10^3
Fish eggs	422	2,242	277	1,146
Fish larvae	1,864	10,469	268	274
No. fish families	9	11	15	17
Sponges	1	0	8	6
Corals, etc.	5	6	44	29
Worms	15	249+	101	66
Clams, etc.	35	11	104+	28
Crustaceans	783	2,741	1,207	1,712
No. crustacean families	13	18	19	19
Sea stars, etc.	4	2	81	28
Fish	104	215	240	250
No. fish families	17	10	17	16

a shallower average depth. The banks are heavily forested with mangroves, principally <u>Rhizophora</u>, and consequently there seems to be less erosion of the banks, resulting in lower average turbidity values (Tables IV and V). The Vung-Tau Region is not subjected to any sewage or industrial wastes, except for a few villages to the northeast near Phuoc-Le (Ba-Ria) and west of the town of Vung-Tau at Xa-Thang. Throughout its area, the Vung-Tau Region closely resembles the undisturbed mangrove forest of parts of Southwest Florida; thus, in part because some comparable qualitative and quantitative information is available from South Florida, the Vung-Tau Region was considered to be a reasonably useful control area.

Collections were made to obtain representative kinds of animals and plants from many stations over a relatively wide geographical region in both the defoliated and nondefoliated areas. We attempted to characterize the physical environment in each locality in relation to the organisms found there. Lack of time and funds precluded the collection and analysis of the chemical environment or chemical nutrient cycles at each station.

Environmental data were based upon water samples collected at the surface, at a middle depth (half-way to the bottom), and just off the bottom. Water temperature and dissolved oxygen content at each collection station were determined with a battery-operated YSI meter. Water salinity was determined from water samples, which were analyzed at the end of the day using a Brix refractometer. Values for pH were determined in the field using a battery-powered pH meter. The turbidity was determined from water samples collected in the field and was subsequently measured at the

Table V.

Hydrographic and biological data collected in mangrove region of SVN, 1972-73. The Rung-Sat is defoliated; Vung-Tau is nondefoliated (control) region. Wet-season collections were made in October and November 1972. Dry-season collections were made in January 1973. Dashes in columns indicate sample not collected. Maximum sample depth is the depth of the bottom water sample.

RUNG-SAT (defoliated) -- wet season

VND stations	10	16	12	14	32	24	18	20	30	22	28	26	34	Average
Maximum water depth, m	17	15	16	15	11	25	12	13	11	20	30	3	10	
Maximum sample depth, m	12	11	12	12	8	12	10	12	11	12	12	3	7	
<u>Temperature, °C</u>														
Surface sample	28.1	28.8	28.5	28.3	30.0	29.3	28.0	28.9	29.8	29.3	29.6	29.6	29.4	29.0
Middle sample	27.9	28.0	28.2	28.1	30.0	-	28.2	-	28.5	-	29.2	-	29.1	28.6
Bottom sample	28.0	28.0	28.0	28.0	29.8	-	28.2	-	28.9	-	29.2	-	29.1	28.6
Average	28.0	28.3	28.2	28.1	29.9	29.3	28.1	28.9	29.1	29.3	29.3	29.6	29.2	28.8
<u>Oxygen, ppm</u>														
Surface sample	3.8	4.1	3.9	3.7	4.3	3.6	3.9	3.2	4.6	3.5	5.0	6.0	6.0	4.3
Middle sample	3.7	4.0	3.5	3.5	4.2	3.2	3.4	3.2	4.3	3.5	4.9	-	6.0	4.0
Bottom sample	3.8	3.9	3.4	3.6	4.1	3.3	3.5	3.1	4.4	3.5	4.8	5.6	5.9	4.1
Average	3.8	4.0	3.6	3.6	4.2	3.4	3.6	3.2	4.4	3.5	4.9	5.8	6.0	4.1
<u>% of oxygen saturation</u>														
Surface sample	59	66	62	58	71	58	61	52	75	56	82	98	97	69
Middle sample	58	63	55	55	69	-	53	-	68	-	79	-	97	66
Bottom sample	59	61	53	56	67	-	55	-	71	-	77	-	95	66
Average	59	63	57	56	69	58	56	52	71	56	79	98	96	67
<u>Salinity, °/oo</u>														
Surface sample	0.0	0.2	1.1	2.3	5.5	8.1	7.7	12.5	13.1	18.1	17.7	24.1	24.9	10.4
Middle sample	0.0	0.1	1.5	2.5	8.3	12.5	11.3	12.9	12.5	15.3	20.7	-	25.3	10.2
Bottom sample	0.2	0.2	3.3	2.7	17.3	14.5	18.5	13.3	17.9	14.1	23.9	26.7	26.5	14.5
Average	0.1	0.2	2.0	2.5	10.4	11.7	12.5	12.9	14.5	15.8	20.8	25.4	25.6	11.5

Table V, continued.

RUNG-SAT (defoliated) -- wet season - (cont'd.)

VND stations	10	16	12	14	32	24	18	20	30	22	28	26	34	Average
Maximum water depth, m	17	15	16	15	11	25	12	13	11	26	30	3	10	
Maximum sample depth, m	12	11	12	12	8	12	10	12	11	12	12	3	7	
pH														
Surface sample	6.7	6.7	6.7	7.0	7.4	7.4	7.2	7.5	7.7	7.6	8.0	7.8	8.2	7.4
Middle sample	6.8	7.3	6.9	7.1	7.6	7.6	7.4	7.7	7.8	7.8	8.1	-	8.3	7.5
Bottom sample	6.8	7.2	6.8	7.0	7.7	7.7	7.8	7.6	8.2	7.9	8.1	7.9	8.3	7.6
Average	6.8	7.1	6.8	7.0	7.6	7.6	7.5	7.6	7.9	7.8	8.1	7.9	8.3	7.5
Turbidity, JTU														
Surface sample	60	49	62	130	20	50	94	220	14	77	13	12	4	62
Plankton, surface[f]														Total
Copepods	658[a]	260[a]	595	347	602[a]	742[a]	538[a]	137[b]	862[a]	159[b]	370[b]	201[a]	207[b]	127[c]
Diatoms	0	30	686	-	248[b]	594[b]	843[a]	705[b]	445[b]	696[b]	267[c]	863[b]	431[c]	106[d]
Fish eggs	0	0	0	0	0	0	0	0	0	0	113	200	109	422
Fish larvae	132	7	22	42	29	37	255	716	7	553	25	5	34	1,864
Number of families	4	1	4	4	4	3	4	3	2	6	3	3	5	9
Benthos[f]														
Sponges	0	0	0	0	0	0	0	0	0	0	0	0	1[e]	1
Corals, hydroids, & anemones	0	0	0	0	0	1	0	0	0	2	1	0	1	5
Worms	0	5	0	1	0	0	0	2	0	6	0	1	0	15
Clams, snails, & squids	0	0	0	0	1	6	0	2	4	4	2	12	4	35

[a] Number X 10^1
[b] Number X 10^2
[c] Number X 10^3
[d] Number X 10^4
[e] Fragments (considered as one individual)
[f] Number of individuals

Table V, continued.

RUNG-SAT (defoliated) -- wet season - (cont'd.)

VND stations	10	16	12	14	32	24	18	20	30	22	28	26	34	Total
Maximum water depth, m	17	15	16	15	11	25	12	13	11	20	20	3	10	
Maximum sample depth, m	12	11	12	12	8	12	10	12	11	12	12	2	7	
Benthos (cont'd.)														
Shrimp & crabs, etc.	21	32	1	6	3	121	388	94	64	32	8	7	6	783
Number of families	2	2	1	4	2	7	6	8	6	6	1	4	3	13
Sea stars, brittlestars, & urchins	0	0	0	0	0	1	0	0	0	1	1	0	1	4
Fishes (benthic)	5	15	1	1	3	16	8	22	2	18	9	4	0	104
Number of fish families	2	5	1	1	3	8	2	6	2	4	6	3	0	17

Table V, continued.

RUNG-SAT (defoliated) -- dry season

VND stations	66	64	62	60	80	74	72	68	70	78	76	Average
Maximum water depth, m	17	20	15	15	14	7	20	25	20	8	30	
Maximum sample depth, m	12	12	12	12	12	7	12	12	12	8	12	
Temperature, ^{o}C												
Surface sample	28.8	28.1	28.0	27.5	27.8	27.9	28.1	27.2	27.9	27.2	27.3	27.8
Middle sample	28.0	27.7	27.5	27.1	27.3	27.4	27.1	27.0	27.1	27.0	27.0	27.3
Bottom sample	27.9	27.8	27.2	27.0	27.1	27.2	27.0	27.0	27.0	27.0	27.0	27.2
Average	28.2	27.9	27.6	27.2	27.4	27.5	27.4	27.1	27.3	27.1	27.1	27.4
Oxygen, ppm												
Surface sample	3.7	3.8	3.8	5.3	4.1	4.5	4.6	5.1	5.5	5.1	5.3	4.6
Middle sample	3.3	3.3	3.2	4.7	3.9	4.5	4.5	4.6	5.0	4.6	4.9	4.2
Bottom sample	3.0	3.6	3.4	4.6	3.8	4.5	4.5	4.7	5.1	4.4	5.0	4.2
Average	3.3	3.6	3.5	4.9	3.9	4.5	4.5	4.8	5.2	4.7	5.1	4.4
% of oxygen saturation												
Surface sample	60	59	59	83	64	70	72	78	86	78	82	72
Middle sample	52	52	50	72	60	69	69	71	77	71	75	65
Bottom sample	47	56	52	71	58	69	69	72	78	68	77	65
Average	53	56	54	75	61	69	70	74	80	72	78	67
Salinity, $^{o}/oo$												
Surface sample	2.3	3.5	6.5	15.9	17.5	14.5	20.9	22.5	24.5	25.7	27.3	16.5
Middle sample	3.1	4.3	6.5	15.7	-	18.9	21.3	23.3	24.9	25.9	27.3	17.1
Bottom sample	3.5	4.3	6.5	15.5	17.9	20.5	21.3	23.3	26.1	25.9	27.3	17.5
Average	3.0	4.0	6.5	15.7	17.7	18.0	21.2	23.0	25.2	25.8	27.3	17.0
pH												
Surface sample	6.9	6.0	7.1	7.4	7.1	7.3	7.5	7.7	7.7	7.7	7.8	7.4
Middle sample	6.8	6.9	7.0	7.2	7.2	7.3	7.5	7.6	7.6	7.6	7.8	7.3
Bottom sample	6.8	6.9	7.2	7.5	7.2	7.4	7.5	7.6	7.7	7.6	7.7	7.4
Average	6.8	6.6	7.1	7.4	7.2	7.3	7.5	7.6	7.7	7.6	7.8	7.4

Table V, continued.

RUNG-SAT (defoliated) -- dry season - (cont'd.)

VND stations	66	64	62	60	80	74	72	68	70	78	76	Average
Maximum water depth, m	17	20	15	15	14	7	20	25	20	8	30	
Maximum sample depth, m	12	12	12	12	12	7	12	12	12	8	12	
Turbidity, JTU												
Surface	40	40	120	90	35	22	38	20	50	27	125	55
Plankton, surface[f]												Total
Copepods	691[a]	144[b]	507[a]	598[a]	217[b]	434[a]	239[b]	752[a]	114[b]	653[a]	974[a]	117[c]
Diatoms	0	61	206	676	106[b]	715	981[a]	415[a]	535[a]	511[a]	891[a]	456[b]
Fish eggs	0	0	0	1	0	0	38	368	325	569	941	2,242
Fish larvae	345	572	1,270	2,212	1,246	530	644	1,429	1,057	470	694	10,469
Number of families	3	4	4	4	4	3	4	7	3	5	5	11
Benthos[f]												
Sponges	0	0	0	0	0	0	0	0	0	0	0	0
Corals, hydroids, & anemones	0	0	1	1	0	0	0	0	1	0	3	6
Worms	0	0	243+	0	0	1	0	0	0	0	5	249+
Clams, snails, & squids	0	0	2	0	0	4	0	0	0	0	5	11
Shrimp & crabs, etc.	3	326	337	358	254	121	351	281	307	218	185	2,741
Number of families	2	6	7	3	6	10	2	5	4	6	8	18
Sea stars, brittlestars, & urchins	0	0	0	0	0	0	0	0	0	1	1	2
Fishes	1	2	12	1	12	18	10	7	2	137	13	215
Number of families	1	2	3	1	4	7	3	3	2	5	5	10

[a]Number X 10^1
[b]Number X 10^2
[c]Number X 10^3
[d]Number X 10^4
[f]Number of individuals

Table V, continued.

VUNG-TAU (nondefoliated) -- wet season

VND stations	42	44	40	48	56	58	50	52	36	38	46	54	Average
Maximum water depth, m	2	3	9	6	3	12	7	6	4	10	5	6	
Maximum sample depth, m	2	3	4	6	3	8	7	6	4	10	5	6	
Temperature, °C													
Surface sample	29.8	29.8	29.3	29.8	29.9	29.6	29.9	29.8	30.0	29.7	29.8	29.9	29.8
Middle sample	-	-	-	29.2	-	29.0	29.2	29.2	-	-	-	29.8	29.3
Bottom sample	28.8	29.1	29.2	29.1	28.5	29.0	29.8	29.2	29.5	-	29.4	29.8	29.2
Average	29.3	29.5	29.3	29.4	29.2	29.2	29.6	29.4	29.8	29.7	29.6	29.8	29.5
Oxygen, ppm													
Surface sample	5.3	4.9	5.3	5.4	5.5	5.7	5.7	5.9	6.5	-	5.4	6.5	5.6
Middle sample	-	-	-	5.3	-	5.8	5.5	5.8	-	-	-	6.5	5.8
Bottom sample	4.9	4.6	4.8	5.3	5.2	5.6	5.2	5.8	5.9	-	5.1	6.3	5.3
Average	5.1	4.8	5.1	5.3	5.4	5.7	5.5	5.8	6.2	-	5.3	6.4	5.6
% of oxygen saturation													
Surface sample	87	80	85	89	90	93	93	97	107	-	89	107	92
Middle sample	-	-	-	85	-	94	89	94	-	-	-	107	94
Bottom sample	80	74	77	85	83	90	85	94	97	-	82	103	86
Average	84	77	81	86	87	92	89	95	102	-	86	106	90
Salinity, °/oo													
Surface sample	21.3	25.7	27.3	27.1	27.3	28.1	28.1	28.3	26.5	28.5	30.1	28.9	27.3
Middle sample	-	-	-	27.5	-	28.1	28.3	28.5	-	28.5	-	29.1	28.3
Bottom sample	26.7	27.1	27.3	27.7	27.9	28.1	28.3	28.7	30.5	28.5	27.5	29.3	28.1
Average	24.0	26.4	27.3	27.4	27.6	28.1	28.2	28.5	28.5	28.5	28.8	29.1	27.8
pH													
Surface sample	7.6	7.9	7.9	7.6	8.1	8.1	7.7	8.4	8.1	8.3	8.2	8.4	8.0
Middle sample	-	-	-	7.6	-	8.2	7.8	8.4	-	-	-	8.5	8.1
Bottom sample	7.7	7.9	7.9	7.8	8.1	8.2	7.7	8.3	8.1	-	8.2	8.5	8.0
Average	7.7	7.9	7.9	7.7	8.1	8.2	7.7	8.4	8.1	8.3	8.2	8.5	8.0

Table V, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	48	56	58	50	52	36	38	46	54	Average
Maximum water depth, m	2	3	9	6	3	12	7	6	4	10	5	6	
Maximum sample depth, m	2	3	4	6	3	8	7	6	4	10	5	6	
Turbidity, JTU													
Surface	21	7	7	6	22	8	4	4	3	3	6	4	8
Plankton, surface[f]													Total
Copepods	598[a]	137[b]	130[b]	161[b]	204[b]	386[b]	405[b]	416[b]	405[a]	222[b]	222[b]	342[b]	273[c]
Diatoms	890[a]	626[a]	470[a]	475[b]	102[c]	290[c]	139[d]	823[c]	530[c]	629[c]	407[b]	124[d]	511[d]
Fish eggs	0	1	0	1	0	3	12	2	180	27	0	51	277
Fish larvae	15	11	6	10	36	12	12	21	113	20	4	8	268
Number of families	2	4	4	3	5	6	6	4	5	6	2	4	15
Benthos[f]													
Sponges	0	1[e]	1[e]	0	2[e]	0	0	2[e]	0	0	0	2	8
Corals, hydroids, & anemones	0	1	2	1	0	0	0	2	10	9	13	6	44
Worms	12	40	0	0	3	0	27	7	1	0	0	11	101
Clams, snails, & squids	15	0	2	0	11	0	25+	28	12	0	11	0	104+
Shrimp & crabs, etc.	26	24	21	18	271	77	214	93	31	42	124	24	1207
Number of families	9	8	4	3	4	13	10	7	8	8	11	6	19
Sea stars, brittlestars, & urchins	1	32	3	2	2	0	4	28	0	0	3	6	81
Fishes	55	5	4	14	56	12	23	12	10	17	29	3	240
Number of families	9	4	3	7	8	6	7	6	6	5	8	1	17

[a] Number X 10^1
[b] Number X 10^2
[c] Number X 10^3
[d] Number X 10^4
[e] Fragments (considered as one individual)
[f] Number of individuals

Table V, continued.

VUNG-TAU (nondefoliated) -- dry season

VND stations	100	90	84	102	104	92	82	86	98	88	96	94	Average
Maximum water depth, m	8	17	6	16	13	16	16	14	8	17	17	25	
Maximum sample depth, m	7	12	6	12	12	12	12	12	8	12	12	12	
Temperature, °C													
Surface sample	27.5	27.5	26.8	27.8	27.5	27.9	27.0	27.7	27.3	27.2	27.7	27.3	27.4
Middle sample	26.8	26.5	26.5	26.6	26.8	26.3	26.3	26.8	26.3	27.0	26.5	26.1	26.5
Bottom sample	26.3	26.3	26.5	26.5	26.5	26.2	26.2	26.8	26.3	26.9	26.0	26.1	26.4
Average	26.9	26.8	26.6	27.0	26.9	26.8	26.5	27.1	26.6	27.0	26.7	26.5	26.8
Oxygen, ppm													
Surface sample	6.8	7.5	5.8	6.8	7.2	7.8	6.1	6.1	6.4	6.9	6.6	6.3	6.7
Middle sample	6.5	7.0	5.7	6.4	6.5	6.5	5.9	6.0	6.0	6.8	5.9	6.0	6.3
Bottom sample	5.9	6.9	5.7	6.3	6.6	6.3	5.8	5.8	6.0	6.8	5.7	5.9	6.1
Average	6.4	7.1	5.7	6.5	6.8	6.9	5.9	6.0	6.1	6.8	6.1	6.1	6.4
% of oxygen saturation													
Surface sample	106	117	89	106	113	122	94	95	98	106	103	97	104
Middle sample	100	108	88	98	100	98	89	92	91	105	91	91	96
Bottom sample	89	105	88	97	102	95	88	89	91	105	86	89	94
Average	98	107	88	100	105	105	90	92	93	105	93	92	98
Salinity, °/oo													
Surface sample	27.7	28.1	30.1	28.9	29.9	27.7	30.7	30.7	29.5	31.3	29.1	30.1	29.5
Middle sample	29.1	30.7	30.5	30.5	30.7	32.1	30.7	30.7	31.7	31.1	33.5	32.9	31.2
Bottom sample	30.5	30.9	30.5	31.7	30.7	32.1	30.7	30.7	32.3	31.1	33.5	33.3	31.5
Average	29.1	29.9	30.4	30.4	30.4	30.6	30.7	30.7	31.2	31.2	32.0	32.1	30.7
pH													
Surface sample	8.0	7.9	7.8	8.1	7.9	8.2	7.5	7.6	8.1	7.7	8.0	8.2	7.9
Middle sample	8.0	7.6	7.8	8.1	7.9	8.2	7.8	7.9	8.1	7.7	8.0	8.2	7.9
Bottom sample	8.0	8.1	7.2	8.1	7.9	8.2	7.6	7.7	8.1	7.8	8.0	8.2	7.9
Average	8.0	7.9	7.6	8.1	7.9	8.2	7.6	7.7	8.1	7.7	8.0	8.2	7.9

Table V, continued.

VUNG-TAU (nondefoliated) -- dry season - cont'd.)

VND stations	100	90	84	102	104	92	82	86	98	88	96	94	Average
Maximum water depth, m	8	17	6	16	13	16	16	14	8	17	17	25	
Maximum sample depth, m	7	12	6	12	12	12	12	12	8	12	12	12	
Turbidity, JTU													
Surface	3	3	6	4	3	2	3	4	3	5	2	4	4
Plankton, surface[f]													Total
Copepods	100[b]	362[a]	-	353[a]	574[a]	106[b]	262[b]	789[a]	120[b]	137[b]	879[a]	115[b]	114[c]
Diatoms	572[b]	304[b]	-	135[b]	338[b]	830[a]	285[a]	165[a]	235[b]	377[a]	299[b]	244[b]	229[c]
Fish eggs	109	120	0	15	11	40	4	3	230	2	340	272	1,146
Fish larvae	18	8	31	66	21	27	23	14	9	27	13	17	274
Number of families	3	5	5	7	4	8	4	3	4	2	4	5	17
Benthos[f]													
Sponges	0	0	0	0	0	0	4[e]	0	0	2	0	-	6
Corals, hydroids, & anemones	4	1	1	2	1	0	5	2	3	2	8	-	29
Worms	0	1	4	0	0	0	11	1	1	48	0	-	66
Clams, snails, & squids	0	0	3	1	0	1	7	0	1	12	3	-	28
Shrimp & crabs, etc.	12	40	82	20	50	13	51	125	5	876	438	-	1,712
Number of families	5	6	10	4	8	5	11	7	2	13	13	-	19
Sea stars, brittlestars, & urchins	0	0	3	0	0	1	3	0	0	18	3	-	28
Fishes	20	72	14	14	8	8	2	0	5	3	104	-	250
Number of families	5	3	5	7	4	4	2	0	3	2	6	-	16

[a] Number X 10^1
[b] Number X 10^2
[c] Number X 10^3
[d] Number X 10^4
[e] Fragments (considered as one individual)
[f] Number of individuals

end of the day using a Hach Jackson turbidimeter. At each station, observations were also made on percentage of cloud cover, wind speed and direction, tidal stage and direction, bottom type, and sightings of fish schools and birds.

Biological collections were made for juvenile and adult fishes and invertebrates using a fine-mesh otter trawl. This 10-ft net was dragged on the bottom, behind the boat (36-ft PBR vessels belonging to the South Vietnamese Navy) for 15 minutes. Simultaneously, two fine-meshed nets of 0.5-m diameter for collecting plankton were towed astern just beneath the surface, one net having a mesh size of 0.5 mm (505 μ), the other having a mesh size of 0.1 mm (110 μ). All samples were immediately preserved in formalin for subsequent examination in the laboratory in Miami.

After the biological samples were returned to the laboratory, they were sorted into general groups (e.g., fishes, crabs, shrimps, worms), and then identified as accurately as possible by specialists familiar with each group. Lack of comparative collections and published literature has hindered identification of most groups of aquatic organisms collected in SVN, even though an intensive search of the literature has been made to determine what published information is required for specimen identification.

Three trips were made to the mangrove regions of SVN. The first, in March 1972, was made in order to select collecting sites, to determine the feasibility of using certain types of equipment, and to ascertain the suitability of the PBRs as collecting vessels. A second trip was made in October and November 1972, to collect in the Rung Sat Special Zone and the Vung-Tau Region during the monsoon (wet) season, and a third visit was made in January 1973 to the same areas during the dry season. It was believed that different environmental conditions in the estuaries might be found following extensive runoff from rainfall compared to conditions prevalent during the dry season. During the October-November trip, 13 collections were made in the Rung-Sat Special Zone and 12 in the Vung-Tau Region; during the January trip, 11 collections were made in the Rung-Sat Special Zone and 13 were made in the Vung-Tau Region, yielding a total of 49 collections of environmental and biological data during the wet and dry seasons.

RESULTS

Physical Results: Environmental Data

A comparison of the environments of the two areas shows that the average water temperature was approximately the same in both areas (Table IV). As might be expected during the dry season when air temperatures were cooler, water temperatures were proportionately cooler, but nonetheless were similarly comparable in the two regions. It had been expected that, with the loss of shade offered by the mangrove canopy resulting from defoliation in the Rung-Sat Special Zone, solar heating of shallow tidal waters along the river banks might have resulted in higher water temperatures, but the data do not show that this occurred appreciably. In fact, average surface temperature (Table V) was greater in Vung Tau (29.8°C) than in the Rung-Sat (29.0°C), possibly because the average depth is less in the former region, thus permitting solar heating to occur more quickly. Probably the large volume of water and extensive tidal stirring of the water columns in the Rung-Sat Special Zone quickly mixes any locally heated water with that in the main channels.

Dissolved oxygen, which is a limiting factor in determining the distribution of organisms in the aquatic environment, is statistically lower in the Rung-Sat Special Zone during both wet and dry seasons, and may well be a direct result of defoliation. The large amount of organic plant fibers and rootstalks found suspended in the waters of the Rung-Sat Special Zone presumably removes oxygen from the water due to bacterial decomposition. In spite of considerable water turbulence from tidal mixing, average oxygen saturation values were considerably lower in surface waters of the Rung-Sat Special Zone (69% and 72% in the wet and dry seasons, respectively) than in the Vung-Tau Region (93% and 113% in the wet and dry seasons, respectively). This would suggest that microorganisms are removing oxygen from the Rung-Sat Special Zone, and that high turbidity is inhibiting photosynthesis. While the relatively low values of dissolved oxygen and oxygen saturation in the Rung-Sat Special Zone may not actually kill aquatic animals, in combination with other factors such as the relatively high temperatures and the high turbidity level, low oxygen content is probably a factor affecting production and growth of organisms.

Surface salinity during the wet season, as would be expected, averaged lower in the Rung-Sat Special Zone (10.4^{o}/oo) than in the Vung-Tau Region (27.3^{o}/oo) because of the large influx of fresh water from the Saigon and Dong-Nai Rivers. Even after monsoon rains had subsided, salinities remained lower during the dry season in the Rung-Sat Special Zone (16.5^{o}/oo) than in the Vung-Tau Region (29.5^{o}/oo).

During the wet season in the Rung-Sat Special Zone, there was a distinct surface salinity gradient from zero salinity near Nha-Be, in the north, southward to the coastal zone where the surface salinity was 24.9^{o}/oo. At all but two stations, salinity was higher at the surface than at the bottom. At three stations, surface salinity was higher than the mid-depth values, possibly reflecting intrusion of water from shallow tidal channels that had become hypersaline from evaporation during periods of relatively high air temperatures. During the dry season, the gradient was similar (2.3^{o}/oo to 27.3^{o}/oo), though the average surface salinity was higher. At only one station did surface salinity exceed the bottom salinity, thus indicating less hypersaline water entering from shallow channels during the dry season, when air temperatures are lower.

In the Vung-Tau Region, during the wet season, the surface salinity values at one station exceeded that of the bottom sample. Here, with the exception of limited areas of mangrove selectively removed by Vietnamese woodcutters, the mangrove canopy remains relatively intact; hence it would be expected that evaporation of tide pool waters and thus hypersalinity would be less likely to occur. The surface salinity gradients in the Vung-Tau Region were comparable during both the wet (21.3-30.1^{o}/oo) and dry (27.7-30.7^{o}/oo) seasons; less rainfall was received throughout the year than in the Rung-Sat Special Zone.

Prior to our studies, we had considered that pH might be a limiting factor in preventing germination of mangrove seedlings in the Rung-Sat Special Zone because of changes in soil chemistry following the use of defoliants and napalm, and possibly from extensive craterization. In the Rung Sat Special

Zone, surface pH values in the wet season were 6.7 to 8.2, and in the dry season were 6.9 to 7.9; average values for both seasons were identical (7.4). Values of pH in surface waters of the Vung Tau Region for the wet season were 7.6 to 8.4, and in the dry season were 7.5 to 8.2, with average values of 8.0 and 7.9, respectively. The more acidic surface pH values encountered in the Rung-Sat Special Zone are not considered unusually low for a lower salinity region (Kobayashi 1959). If the defoliation and other war-related activities did affect the soils in the mangrove forest, it is not apparent from our samples taken from the main channels or even in tide pools and shallow channels from the mangrove forests themselves (de Sylva 1972). Of surface samples in the Rung-Sat Special Zone, pH values were lower than mid-depth and bottom samples during the wet season. However, during the dry season, values for surface waters exceeded and equalled samples from mid-depth and bottom waters at all but one station. It is not apparent why pH values of surface waters in the Rung-Sat Special Zone should be so high, especially since salinity values were considerably lower and, especially because pH usually decreases in estuaries as the water becomes less saline. Possibly high pH reflects photosynthetic activity, yet the low percentage of oxygen saturation observed during our daytime collections in the Rung-Sat Special Zone would not indicate high productivity rates.

The last physical measurement examined was that of turbidity, which is an index of water clarity: lower values represent clearer water. For a comparison, the waters of the western shore of southern Biscayne Bay, Florida, a relatively unpolluted, brackish body of water, but revealing the effects of some urbanization, have an average turbidity value of 3.2 JTU

(Jackson Turbidity Units). The average turbidity values for surface waters in the Rung Sat Special Zone for the wet and dry season were 61.9 and 55.2 JTU, respectively; those in the Vung-Tau Region were 7.8 and 3.5 JTU, respectively. This means that the waters of the Rung-Sat Special Zone at comparable seasons were between 8 and 16 times as turbid as the waters of the Vung-Tau Region.

It was not possible to determine what proportion of the turbidity was caused by organic debris or inorganic materials and what was caused by animal and plant plankton. It appeared that most turbidity in the Rung-Sat Special Zone is from organic debris, while that in the Vung-Tau Region is from animal and plant plankton. The striking thing one notices in the Rung-Sat Special Zone is its very high turbidity, with values ranging from a low of 3.5 JTU (near an open, clear bay) to a high of 220 JTU (water resembled cocoa).

Some background information on turbidity in the Rung-Sat Special Zone is available from the U.S. Naval Oceanographic Office (Figure 5). In September 1967, a series of anchor stations in the Saigon, Nha-Be, and Long-Tau Rivers permitted measurements of current speed and the percentage of suspended sediments in the water column of the main channel of the Rung-Sat Special Zone (Kopenski 1968). As the amount of suspended sediment increases, the water clarity decreases and turbidity values correspondingly increase. Examination of the 1967 data shows that the sediment load at that time was quite high, and since these measurements were taken during the period of defoliation of the Rung-Sat, we might assume that the resulting decay of defoliated trees and runoff of debris into the river would have increased the sediment load of the water.

A comparison of the sediment load with current speed, based on the Navy data collected in 1967, shows a good relationship. The faster the current speed, the higher is the concentration of suspended sediments. Because there is a slight lag in concentration of sediments downstream from where each current measurement is made, it is suggested that the tidal current actively stirs up sediments from the bottom and transports them to the surface (upwelling). Further, because of the wide tidal range experienced in the Rung-Sat Special Zone (3-4 m), extensive areas of the eroded shoreline are thus subject to tidal scouring as the tidal current increases. The resulting silt load picked up during tidal scouring would greatly increase the sediment load.

Biological Results

Plankton: Microplankton. Plankton, or the drifting assemblage of small animals and plants, was studied because it offers a good clue to the comparative health of a region. Plankton not only serves as food in the complex aquatic food web for a host of other organisms, but it also comprises larvae of edible shrimps, crabs, clams, oysters, and snails. Because of its large numbers and diversity, plankton can always be found under a variety of conditions, both ideal and adverse. Yet from a careful study of what kinds of plankton are present, it is possible to infer if the plankton is representative of a "healthy" environment, and if the plankton will be eaten by larger organisms to contribute to the economy and success of the aquatic ecosystem. It was thus believed that a thorough analysis of the plankton might give clues, based on knowledge of planktonic communities from other, similar tropical regions, to the relative health of the mangrove ecosystem in SVN.

In the only comprehensive work attempted on Vietnamese plankton (Shirota 1966), it was explained that studies have exclusively concerned classification of freshwater and marine plankton rather than the ecology of the organisms. Freshwater forms have been studied largely in fish-culture ponds and in lakes and marshes, while the marine plankton has been examined in the relatively oceanic habitat of the Nha-Trang area. A search of the literature and consultation with Vietnamese biologists, including the Directors of Fisheries and of the Oceanographic Institute at Nha-Trang, have confirmed the total lack of material, either samples or data, on estuarine plankton. Inasmuch as there are no data with which to compare the information collected in the Rung-Sat Special Zone and the Vung-Tau Region, we must evaluate the results in terms of reports from somewhat similar areas elsewhere and past experience. The following remarks concern the phytoplankton and zooplankton collected with a 0.1 -mm (110 μ) mesh net at the end of the wet (monsoon) season, October-November 1972, and during the dry season, January 1973.

In the wet season, the brown color and turbidity of the water in the Rung-Sat Special Zone, particularly near the defoliated areas in the region southeast of Nha-Be, led us to believe that the samples contained a large mineral fraction, but this did not prove to be true. Instead, extreme turbidity was directly related to finely-divided debris from higher plants, presumed to be bits of grass and mangrove stems and leaves. This will be discussed later in connection with the abundance of organisms.

The diversity of living plants and animals in both study areas in all except a few samples was far greater than anticipated. Four major kinds of phytoplankton were found--blue-green and green algae, diatoms, and dinoflagellates. These were represented by nine genera (Table VI), but primarily by the diatoms Coscinodiscus spp., which almost invariably dominated the collections. The following ten phyla comprise the zooplankton: Protozoa, Coelenterata, Ctenophora, Nematoda, Mollusca (snail and clam larvae), Annelida (larval and adult worms), Arthropoda (mostly crustaceans), Chaetognatha, Echinodermata (larvae), and Chordata (ascidians and fish larvae). The Arthropoda, numerically the most important among the invertebrate animals, were represented by freshwater cladocerans at stations of 0.0-0.2°/oo salinity (in the Rung-Sat Special Zone) and, at the more saline stations, by larval barnacles, very abundant copepods (approximately 10 species of calanoids, 6 of cyclopoids and 6 of harpacticoids, with large numbers of their larval and juvenile forms), adults and larvae of several shrimp-like animals, and the larvae and juveniles of many kinds of crabs and shrimps (decapods). In all, 52 kinds of invertebrate animals were enumerated (Table VI). With regard to classification, most of the adult planktonic organisms offer fewer problems than the bottom-living invertebrates and the fishes because some species and many genera are cosmopolitan.

A few organisms appear to be indicators of fresh and saline parts of the river, for example the cladocerans Alona sp. and Bosmina sp., which occurred only in fresh water, and the ctenophore Pleurobrachia pileus as well as chaetognaths, which were abundant only at the more saline stations.

Table VI.

List of planktonic organisms collected with 100-μ plankton nets in the Rung-Sat Special Zone and the Vung-Tau Region, SVN, October-November 1972 and January 1973.

PHYTOPLANKTON

Cyanophyta, Oscillatoriaceae

- *Trichodesmium* sp.

Chlorophyta, Volvocaceae

- *Volvox* sp.

Chlorophyta, Zygnemataceae

- *Spirogyra* sp.

Chrysophyta, Coscinodiscaceae

- *Coscinodiscus* sp.

Chrysophyta, Chaetoceraceae

- *Chaetoceros* spp.

Chrysophyta, Biddulphiaceae

- *Triceratium* sp.

Chrysophyta, Fragilariaceae

- *Asterionella* sp.
- *Thalassiothrix* sp.

Pyrrophyta, Peridiniaceae

- *Ceratium* sp.

ZOOPLANKTON

Protozoa, Radiolaria

- *Amphilithium* sp.

Coelenterata

- *Hippopodius* sp.
- hydrozoan medusae
- scyphozoan medusae

Ctenophora

- *Pleurobrachia pileus*

Aschelminthes, Nematoda

Mollusca

- gastropod veligers
- pelecypod veligers

Annelida

- *Sagitella* sp.
- polychaete larvae

Arthropoda, Crustacea

- Cladocera
  - *Alona* sp.
  - *Bosmina* sp.

Table VI, continued.

Copepoda, Calanoida

- *Acartia* sp. 1
- *Acartia* sp. 2
- *Centropages* sp. 1
- *Centropages* sp. 2
- *Eucalanus* sp.
- *Euchaeta* sp.
- *Labidocera* sp.
- *Paracalanus* sp.
- *Pseudodiaptomus* sp.
- *Temora* sp.

Copepoda, Cyclopoida

- *Corycaeus* sp.
- *Cyclops* sp.
- *Oithona* sp.
- *Oncaea* sp.
- cyclopoid sp. 1
- cyclopoid sp. 2

Copepoda, Harpacticoida

- *Canthocamptus* sp.
- *Clytemnestra* sp.
- *Euterpe* sp.
- *Euterpina* sp.
- *Laophonte* sp.
- *Microsetella* sp.

Cirripedia

- nauplii
- metanauplii
- cypris larvae

Cumacea

Isopoda

- cryptoniscus larvae

Amphipoda

- *Vibilia* sp.

Decapoda

- *Lucifer typus*
- *Lucifer* zoea and mysis
- caridean zoea and mysis
- brachyuran zoea and mysis

Stomatopoda

- *Squilla* larvae

Chaetognatha

- *Sagitta enflata*
- *S. neglecta*
- *S. friderici*

Echinodermata

- ophiopluteus larvae
- juvenile asteroids

Chordata

- ascidian larvae
- *Oikopleura* sp.
- fish larvae

To evaluate the distribution and abundance of plankton in the estuary, copepods, crab larvae, chaetognaths, and diatoms were selected as guides. At all stations except in fresh water, total numbers of copepods of all species and their developmental stages and of the diatom Coscinodiscus were relatively high. However, these numbers were distinctly lower at stations near defoliated areas, where the salinity did not exceed 20°/oo, than at stations with higher salinities near nondefoliated mangrove stands. Probably in part owing to high levels of nutrients during the wet season, the majority of these most abundant groups were then far more numerous than in the dry season. Only mollusk and crab larvae and the copepod genus Acartia occurred in significantly higher numbers in the dry season. These data are summarized in Table VII, in which average numbers of organisms/m^3 at all stations combined are compared.

In wet and dry seasons, diatoms showed strong correlation with low turbidity and high salinity. Although they were present over a wide range of salinity (6.5-32.0°/oo), the greatest numbers in both seasons were found in the most saline, least turbid waters. Copepods, however, were abundant in almost all parts of both study areas. In the wet season, 80 percent occurred in waters where the turbidity measured 3-20 JTU, and 20 percent occurred in waters of 21-220 JTU, but in the dry season the percentages were approximately equal, owing to the abundance of certain kinds (the calanoid Acartia and species of cyclopoids) that are particularly tolerant of low salinity. It appears that these are organisms that contribute to the high turbidity of the less saline waters.

Chaetognaths, perhaps in response to the abundance of copepods on

Table VII.

Average number of organisms collected in a cubic meter of water in wet and dry seasons, in the Rung-Sat Special Zone and the Vung-Tau Region, SVN, October-November 1972 and January 1973.

Average No./ m^3, All Stations Combined

GROUP	WET	DRY
Coscinodiscus spp.	246,693	12,487
Total Copepoda[a]	15,975	10,507
Calanoid Copepoda	6,916	5,132
Calanoida, *Acartia*	799	1,209
Cyclopoid Copepoda	7,149	4,031
Harpacticoid Copepoda	204	281
Brachyuran larvae	34	1,299
Gastropod veliger larvae	152	1,896
Pelecypod larvae	301	444

[a]This figure includes adults, juveniles, and identifiable larvae as well as nauplii which could not be assigned to order.

which they feed, were often common in areas of relatively low salinity (15-20°/oo).

Crab larvae were rare during the wet season when they were strongly associated with low turbidity and high salinity. Conversely, they were among the most numerous organisms in the dry season and 94 percent occurred in waters of 21-125 JTU rather than in less turbid waters. Probably a breeding period accounts for the large difference in total numbers, and the presence of different species may well explain the change in environmental preference.

The actual percentage distribution of these key groups in wet and dry seasons, arranged both in order of increasing turbidity and increasing salinity, are shown in Tables VIII and IX.

Larvae of snails and bivalve mollusks (gastropod and pelecypod veligers) occurred in considerable numbers over most of the range of conditions, and often they were abundant in the Rung-Sat region. For example, 6753 snail larvae/m^3 of water filtered were collected at a station where the salinity was 6.5°/oo and the turbidity 120 JTU; 1388 bivalve larvae/m^3 were taken in water measuring 4.0°/oo and 40 JTU. Snail larvae were lacking at stations of highest turbidity (Station Nos. 15 and 21) during the wet season but were very numerous during the dry season, as shown in the example just given. Clam larvae, never as numerous, were most abundant in the Vung-Tau Region during the wet season but occurred through a broader range of conditions in dry season. Because several species of both groups are involved, each with its own breeding behavior, and because the larvae cannot now be identified to species, it cannot be

Table VIII.

Percentages of groups of organisms arranged in order of increasing salinity at stations sampled during wet and dry seasons in the Rung-Sat Special Zone and Vung-Tau Region, SVN, October-November 1972 and January 1973. Figures for salinity ($^{o}/oo$) and percentages of samples are expressed as X 10.

WET_SEASON_DATA[a]

STA	SAL	COSC	COPE	BRAC	CHAE
11	1	0	16	2	0
17	2	0	7	7	0
13	20	0	1	10	0
15	25	0	1	25	0
33	104	4	15	13	0
25	117	10	19	14	1
19	125	1	13	20	10
21	129	11	34	5	7
31	145	7	22	32	0
23	158	11	40	178	87
29	208	43	93	42	41
43	240	1	15	0	0
27	254	14	5	10	2
35	256	70	52	116	50
45	264	1	34	0	8
41	273	1	33	7	5
49	274	8	40	17	16
57	276	17	51	19	66
59	281	47	97	8	26
51	282	225	102	32	235
37	285	133	104	50	73
39	285	86	10	8	22
53	285	102	56	182	177
47	288	7	56	2	52
55	291	200	86	201	121

DRY_SEASON_DATA

STA	SAL	COSC	COPE	BRAC	CHAE
67	30	0	30	1	0
65	40	0	62	1	0
63	65	1	22	3	0
61	157	2	26	9	0
81	177	39	94	112	53
75	180	3	19	8	11
73	212	36	103	129	187
69	230	15	33	41	30
71	252	19	49	467	53
79	258	19	28	63	24
77	273	32	42	149	40
101	291	208	43	3	191
91	299	111	16	0	22
103	304	49	15	2	30
105	304	123	25	1	11
93	306	30	46	4	107
83	307	10	113	1	27
87	307	6	34	2	3
99	312	85	52	1	64
89	313	14	59	2	26
97	320	109	38	0	33
95	321	89	50	0	90

[a] **Abbreviations: STA = station, SAL = salinity, COSC = Coscinodiscus (diatom), COPE = total Copepoda, including larval and juvenile forms, BRAC = Brachyuran (crab) larvae, CHAE = Chaetognatha.**

Table IX.

Percentage of groups of organisms arranged in order of increasing turbidity at stations sampled during wet and dry seasons in the Rung-Sat Special Zone and Vung-Tau Region, SVN, October-November 1972 and January 1973. Turbidity is measured in JTU; percentages of samples are expressed as X 10.

WET_SEASON_DATA[a]

STA	TURB	COSC	COPE	BRAC	CHAE
35	3	70	52	116	50
37	3	133	104	50	73
39	3	86	10	8	22
53	3	102	56	182	177
51	4	225	102	32	235
55	4	200	86	201	121
49	6	8	40	17	16
47	6	7	56	2	52
45	7	1	34	0	8
41	7	1	33	7	5
59	8	47	97	8	26
27	12	14	5	10	2
29	13	43	93	42	41
31	14	7	22	32	0
33	20	4	15	13	0
43	21	1	15	0	0
57	22	17	51	19	66
17	49	0	7	7	0
25	50	10	19	14	1
11	60	0	16	2	0
13	62	0	1	10	0
23	77	11	40	178	87
19	94	1	13	20	10
15	130	0	1	25	0
21	220	11	34	5	7

DRY_SEASON_DATA

STA	TURB	COSC	COPE	BRAC	CHAE
93	2	30	46	4	107
97	2	109	38	0	33
83	3	10	113	1	27
91	3	111	16	0	22
99	3	85	52	1	64
101	3	208	43	3	191
105	3	123	25	1	11
87	4	6	34	2	3
95	4	89	50	0	90
103	4	49	15	2	30
89	5	14	59	2	26
69	20	15	33	41	30
75	22	3	19	8	11
79	27	19	28	63	24
81	35	39	94	112	53
73	38	36	103	129	187
65	40	0	62	1	0
67	40	0	30	1	0
71	50	19	49	467	53
61	90	2	26	9	0
63	120	1	22	3	0
77	125	32	42	149	40

[a] Abbreviations: STA = station, TURB = turbidity, COSC = Coscinodiscus (diatom), COPE = total Copepoda, including larval and juvenile forms, BRAC = Brachyuran (crab) larvae, CHAE = Chaetognatha.

stated that edible species are reproducing, only that such numbers and diversity of larval life suggest a viable system.

Very little evidence of seasonal restriction was found. Stomatopod larvae were caught only during the dry season and at rather low salinities, ranging from 17.7^{o}/oo, where they were most numerous, to 27.3^{o}/oo. Also, echinoderm larvae, very rare in the wet season, were comparatively widespread in the dry season, occurring in low numbers at 16 of the 22 stations.

In summary, both study areas are rich both in variety of planktonic organisms and in numbers of individuals. These values increase, as one would expect in the tropics, with an increase in salinity. The other environmental parameter measured that appears to have influenced diversity and density of plankton is turbidity. (As far as invertebrate plankton is concerned, the range of temperature is miniscule, oxygen was not at limiting levels, and the relationship, if any, of pH was obscure.) At stations near defoliated areas, turbidity was very high, reaching 220 JTU. Although the average numbers of the most abundant organisms per cubic meter of water in the Rung-Sat Special Zone were far lower than at stations having higher salinity values, the average volume of organic material was much higher in the Rung-Sat Special Zone. This fact results mainly from the large volume of organic debris, consisting principally of decayed fragments of higher plants. These persistent bits of cellulose are kept in suspension by tidal action and the propellers and wakes of river traffic. It is reasonable to infer that the resultant reduction of light in the water column directly affects productivity in this portion of the Rung-Sat Special Zone. In contrast, the high volume of organic material in the Vung-Tau Region reflects the abundance of phytoplankton and zooplankton, rather than detritus. The huge numbers of *Coscinodiscus* as well as copepods and larval forms indicate a healthy and richly productive environment in the Vung-Tau Region.

Plankton: Fish Eggs and Larvae. Larval fishes are important indicators of water quality because adults can only spawn in waters that are reasonably free from contaminants (Hynes 1971). Eggs thus spawned either float at or near the surface, or sink to or near the bottom, where they may become attached to vegetation. The eggs must be subjected to optimum environmental conditions if they are to survive to hatch and if the developing larval stages are subsequently to grow into the adult stage (Hempel 1965). Hence, polluted environments generally do not permit the production of large numbers of eggs and larvae by many species of fish (de Sylva 1970). However, occasionally pollution will result in nutrient fertilization of the aquatic environment so that such habitats may be actually favorable to some fish species (Mansueti 1962). When this occurs, usually the number of different *kinds* of species able to spawn is drastically reduced, and one or several tolerant forms survives to occupy the living space vacated by the more sensitive organisms that have not survived. This results in a few tolerant species producing large numbers of eggs; consequently a large fish population with a great number of only a few species evolves. In contrast, a healthy environment comprises a large number of different species, each producing a moderate number of eggs. Thus, the relative "health" of an area also can be examined by comparing the species diversity, or the number of different kinds of organisms present, rather than assessing the total number of organisms present.

It is virtually impossible to identify preserved fish eggs. However, the total numbers of fish eggs were enumerated because the presence of fish eggs usually indicates that adult fishes must have spawned nearby, and that, presumably, this necessarily occurs in a relatively healthy environment.

Fish eggs were 1.5 to 2 times as numerous in the Rung-Sat Special Zone during the wet and dry seasons, respectively, as they were in the Vung-Tau Region (Table IV). In the Rung-Sat Special Zone, eggs were taken at 3 of 13 stations (23%) during the wet season and at 6 of 11 stations (55%) during the dry season. In comparison, in the Vung-Tau Region, eggs occurred at 8 of 12 stations (67%) during the wet season and at 11 of 12 stations (92%) during the dry season. The explanation may be that a few very fecund individuals spawned a large number of eggs in a small area, a situation typical of stressed environments.

In the Rung-Sat, low values of pH, oxygen, or both may be factors limiting the spawning and survival of eggs. For example, during the wet season, eggs were taken only when the pH exceeded 7.8, and during the dry season only when the pH exceeded 7.4 (Table V). However, since surface pH values below 7.6 were not encountered in the Vung-Tau samples, comparisons are not possible. A more meaningful relationship appears to exist between the presence of fish eggs and the percent of oxygen saturation in surface waters. In the Rung-Sat Special Zone, no eggs were taken during the dry season when the oxygen saturation was below 72 percent, and during the wet season none occurred when the saturation was below 82 percent. In the Vung-Tau Region, eggs were usually absent when the oxygen saturation fell below 90 percent.

Larval fishes in the Rung-Sat Special Zone were from nearly 7 times to 38 times as abundant as in the Vung-Tau Region during the wet and dry seasons, respectively. Larval fishes occurred at all stations during both seasons and in each study area.

Identification of larval fishes in the estuarine region of Vietnam is extremely difficult because of the lack of studies there, and because literature on larvae is virtually nonexistent. Nonetheless, it was possible to identify many specimens to the family level (Table X). In the Rung-Sat Special Zone, 9 and 11 different families of fishes were represented in larval fish collections during the wet and dry seasons, respectively, while 15 and 17 families occurred in Vung-Tau collections during the same periods.

Within the Rung-Sat Special Zone, the Gobiidae accounted for 93 percent of larvae identified during the wet season and 98 percent of those collected during the dry season. In the Vung-Tau Region, this family was also predominant, but represented only 57 percent of collections during the wet season and 47 percent of the fish families obtained during the dry season. In studies of southern Biscayne Bay, Florida, gobies are indicators of stressed environments (de Sylva 1970); where pollution or alteration of the ecosystem has occurred, this family usually dominates the fish plankton. Thus, the preponderance of Gobiidae in the Rung-Sat Special Zone would indicate a stressed environment, in contrast to a more rich diversification of organisms in the Vung-Tau Region.

Table X.

Larval fish families collected with 0.5-m (505-μ mesh) plankton net in mangrove region of SVN, 1972-73. Numbers in columns are numbers of specimens. The Rung-Sat is defoliated; Vung-Tau is nondefoliated (control) region. Wet season collections were made in October and November 1972. Dry season collections were made in January 1973.

RUNG-SAT (defoliated) -- wet season

VND stations	10	16	17	14	32	18	24	20	30	28	22	26	34	Total
Surface salinity, °/oo	0.0	0.2	1.1	2.3	5.5	7.7	8.1	12.5	13.1	17.7	18.1	24.1	24.9	
<u>Fish families</u>														
Clupeidae (herrings)	0	0	1	1	5	1	1	14	0	0	0	2	19	44
Engraulidae (anchovies)	1	0	4	4	0	5	1	2	0	0	4	0	0	21
Syngnathidae (pipefishes & seahorses)	1	0	0	0	0	0	0	0	0	0	1	0	0	2
?Priacanthidae (bigeyes)	0	0	0	0	0	0	0	0	2	0	0	0	0	2
?Carangidae (jacks)	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Sparidae (porgies)	0	0	0	0	0	0	0	0	0	1	2	1	2	6
Blenniidae (blennies)	3	0	0	2	1	1	0	0	0	14	3	2	0	26
?Clinidae (naked blennies)	0	0	1	0	1	0	0	0	0	0	1	0	8	11
Gobiidae (gobies)	16	1	10	30	20	84	32	698	2	7	513	0	2	1415
Unidentifiable specimens	18	6	6	2	0	2	2	0	1	1	18	0	0	56
Unidentifiable (damaged) specimens	93	0	0	3	2	162	1	2	2	2	11	0	2	280
Total specimens	132	7	22	42	29	255	37	716	7	25	553	5	34	1864
Fish eggs	0	0	0	0	0	0	0	0	0	113	0	200	109	422

Table X, continued.

RUNG-SAT (defoliated) -- dry season

VND stations	66	64	62	74	60	80	72	68	70	78	76	Total
Surface salinity, °/oo	2.3	3.5	6.5	14.5	15.9	17.5	20.9	22.5	24.5	25.7	27.3	
<u>Fish families</u>												
Clupeidae (herrings)	45	30	8	0	5	1	1	9	0	1	3	103
Engraulidae (anchovies)	0	0	6	0	1	0	0	3	1	1	12	24
Syngnathidae (pipefishes & seahorses)	0	0	0	3	2	7	3	1	5	1	3	25
?Atherinidae (silversieds)	5	2	2	0	0	1	1	1	0	0	0	12
Sillaginidae (whitings)	0	0	0	0	0	0	0	1	0	0	0	1
Blenniidae (blennies)	0	0	0	0	0	0	0	0	0	1	0	1
?Eleotridae (sleepers)	0	0	0	1	0	0	0	0	0	0	0	1
Gobiidae (gobies)	293	502	1253	525	2196	1206	628	1344	1043	421	659	10,070
Heterosomata (flounders & soles)	0	3	0	0	0	0	0	0	0	0	0	3
Tetraodontidae (puffers)	0	0	0	0	0	0	0	1	0	0	0	1
Diodontidae (porcupine fishes)	0	0	0	0	0	0	0	0	0	0	1	1
Unidentifiable specimens	2	18	1	0	8	10	10	37	8	43	16	153
Unidentifiable (damaged) specimens	0	17	0	1	0	21	1	32	0	2	0	74
Total specimens	345	572	1270	530	2212	1246	644	1429	1057	470	694	10,469
Fish eggs	0	0	0	0	1	0	38	368	325	569	941	2,242

Table X, continued.

VUNG-TAU (nondefoliated) -- wet season

VND stations	42	44	36	48	40	56	50	58	52	38	54	46	Total
Surface salinity, °/oo	21.3	25.7	26.5	27.1	27.3	27.3	28.1	28.1	28.3	28.5	28.9	30.1	
Fish families													
Clupeidae (herrings)	0	1	1	0	0	1	0	0	0	0	0	0	3
Engraulidae (anchovies)	0	0	0	0	0	0	1	0	0	1	0	0	2
Syngnathidae (pipefishes & seahorses)	0	1	0	0	0	0	0	1	1	3	1	0	7
Mugilidae (mullets)	0	0	0	0	0	0	1	0	0	0	1	0	2
Atherinidae (silversides)	0	0	0	1	0	0	0	0	0	0	0	0	1
Centropomidae (snooks)	0	0	0	0	0	23	0	0	6	0	0	0	29
Sillaginidae (whitings)	7	0	0	0	0	0	0	0	0	0	0	0	7
?Carangidae (jacks)	0	0	0	0	1	0	0	0	0	0	0	0	1
Sciaenidae (croakers)	0	0	2	0	0	0	0	1	0	1	0	0	4
Sparidae (porgies)	0	0	1	0	0	1	1	0	0	0	0	0	3
Scaridae (wrasses)	0	0	0	0	0	0	0	1	0	0	0	0	1
Blenniidae (blennies)	0	0	0	0	1	0	1	0	0	0	0	0	2
?Clinidae (naked blennies)	0	3	3	3	1	4	7	1	8	4	0	3	37
Gobiidae (gobies)	8	4	93	1	3	6	1	5	2	8	2	1	134
Heterosomata (flounders & soles)	0	0	0	0	0	0	0	1	0	1	1	0	3
Unidentifiable specimens	0	2	7	2	0	1	0	2	1	2	3	0	20
Unidentifiable (damaged) specimens	0	0	6	3	0	0	0	0	3	0	0	0	12
Total specimens	15	11	113	10	5	36	12	12	21	20	8	4	268
Fish eggs	0	1	180	1	0	0	12	3	2	27	51	0	277

Table X, continued.

VUNG-TAU (nondefoliated) -- dry season

VND stations	92	100	90	102	96	98	104	84	94	82	86	88	Total
Surface salinity, °/oo	27.7	27.7	28.1	28.9	29.1	29.5	29.9	30.1	30.1	3[illegible].7	30.7	31.3	
Fish families													
Clupeidae (herrings)	2	0	2	6	4	0	0	0	2	0	0	0	16
Engraulidae (anchovies)	1	0	1	5	0	0	1	0	0	0	0	0	8
Syngnathidae (pipefishes & seahorses)	0	0	0	0	0	0	0	4	0	1	0	1	6
Mugilidae (mullets)	0	0	0	0	0	2	1	0	0	0	0	0	3
?Atherinidae (silversides)	0	0	0	0	0	0	0	0	0	1	0	0	1
Centropomidae (snooks)	0	0	1	0	0	0	0	0	0	0	1	0	2
Sillaginidae (whitings)	1	0	0	0	0	0	1	0	2	0	0	0	4
?Carangidae (jacks)	1	0	0	3	0	0	0	0	0	0	0	0	4
Pomadasyidae (grunts)	0	0	0	3	0	0	0	0	0	2	0	0	5
Sciaenidae (croakers)	3	3	0	1	1	1	0	2	2	0	2	0	15
Sparidae (porgies)	3	2	0	0	0	2	0	1	4	0	0	0	12
Scaridae (wrasses)	1	0	0	0	0	0	0	0	0	0	0	0	1
Blenniidae (blennies)	0	0	0	0	0	0	0	1	0	0	2	0	3
?Clinidae (naked blennies)	0	0	1	0	1	0	0	0	0	0	0	0	2
Gobiidae (gobies)	10	12	0	27	0	2	1	9	2	5	0	9	77
Platycephalidae (flatheads)	0	0	3	0	0	0	0	0	0	0	0	0	3

Table X, continued.

VUNG-TAU (nondefoliated) -- dry season (cont'd.)

VND stations	92	100	90	102	96	98	104	84	94	82	86	88	Total
Surface salinity, $^{o}/oo$	27.7	27.7	28.1	28.9	29.1	29.5	29.9	30.1	30.1	30.7	30.7	31.3	
<u>Fish families</u>													
Heterosomata (flounders & soles)	0	0	0	1	1	0	0	0	0	0	0	0	2
Unknown specimens	5	1	0	19	4	0	17	14	5	13	6	17	101
Unidentifiable (damaged) specimens	0	0	0	1	2	2	0	0	0	1	3	0	9
Total specimens	27	18	8	66	13	9	21	31	17	23	14	27	274
Fish eggs	40	109	120	15	340	230	11	0	272	4	3	2	1146

Another measure of richness is given in the variety index (Odum 1971):

$$d = \frac{S}{\sqrt{N}}$$

where d = the diversity index, S = number of species (families in this case), and N = number of individuals.

This index was calculated for the larval fish families listed in Table X, and the values are presented in Table XI. At nearly every station in the Rung-Sat Special Zone, the values are lower than those obtained in the Vung-Tau Region; the weighted index for all stations in the Rung-Sat Special Zone is somewhat higher during the wet season, but the diversity index for the Vung-Tau Region is higher during the dry season. This greater variety of families is, however, partly due to the more saline regime characteristic of the Vung-Tau Region. Nonetheless, collections made in the Rung-Sat Special Zone during the dry season, when salinities are higher (Table IV), still do not reflect the increase in species diversity one might find in regimes of higher salinity.

Because larval fishes can detect visually and thus avoid an oncoming plankton net in clear water, such as is found in South Florida, larger nets are desirable. The use of 1-m nets would obviate this avoidance reaction but 1-m nets could not be used in Vietnam because the large volume of accumulated floating debris in the water would make the net impossible to retrieve. Another factor that should be taken into consideration is that the clearer water in the Vung-Tau Region may permit larval fishes to escape the oncoming net, hence resulting in a lower catch/m^3. Conversely, larvae living in the highly turbid waters of

Table XI.

Diversity indices of larval fish families from surface plankton tows in estuaries of SVN. Stations with comparable surface salinity values are in adjacent columns. Stations are arranged in order of increasing surface salinity.

RUNG-SAT SPECIAL ZONE				VUNG-TAU REGION			
Wet Season		Dry Season		Wet Season		Dry Season	
VND stations	index	VND stations	index	VND stations	index	VND stations	index
10	0.87	66	0.22	42	0.52	92	1.73
16	1.00	64	0.21	44	1.67	100	0.94
12	1.00	62	0.14	36	0.60	90	1.77
14	0.66	74	0.13	48	1.79	102	0.99
32	0.78	60	0.14	40	1.63	96	1.51
18	0.35	80	0.14	56	1.01	98	1.51
24	0.52	72	0.20	50	1.73	104	1.07
20	0.11	68	0.21	58	2.22	84	1.08
30	1.00	70	0.12	52	1.21	94	1.46
28	0.64	78	0.28	38	1.65	82	1.07
22	0.26	76	0.23	54	2.23	86	1.20
26	0.22			46	1.00	88	0.58
34	0.59						
weighted average	0.28		0.16		0.72		1.04

the Rung-Sat Special Zone might not detect the oncoming net, and therefore the catch in the Vung-Tau Region might be greater if 1-m plankton nets could be used.

Benthic Invertebrates. These are animals that live on or near the bottom or burrow into the mud, and include sponges, coelenterates, mollusks, polychaetes, echinoderms, and crustaceans. It is difficult to make direct comparisons of the kinds and numbers of benthos caught in the two study areas because a greater number and diversity of taxonomic groups occur at higher salinities. Nor can we necessarily infer greater productivity in comparing diversity of the number of different taxonomic groups in each region, simply because organisms such as sponges, corals, anemones, squids, oysters, starfish, and crabs are rare or absent in fresh water; these groups increase in numbers of individuals and species as the salinity regime increases (Fischer-Piette 1931).

In the Rung-Sat Special Zone, bottom trawls yielded 844 and 3012 invertebrates during the wet and dry seasons, respectively, while in the Vung-Tau Region there were 1552 and 1876 invertebrates during the wet and dry seasons, respectively (Table XII).

The large numbers of animals in the Rung-Sat are represented by only a few groups. Decapod shrimps formed the bulk of the collections from the Rung-Sat, representing 93 and 91 percent of the invertebrates during the wet and dry seasons, respectively; in the Vung-Tau collections they comprised 78 and 91 percent of the collections during the wet and dry seasons, respectively. In the Rung-Sat Special Zone during the wet season there was a predominance of crustaceans over a bottom salinity range of

Table XII.

Invertebrates and lower chordates collected with 10-ft otter trawl in mangrove region of SVN, 1972-73. Numbers in columns are number of specimens. The Rung-Sat is defoliated; Vung-Tau is nondefoliated (control) region. Wet-season collections were made in October and November 1972. Dry-season collections were made in January 1973. Dashes in columns indicate sample not collected.

RUNG-SAT (defoliated) -- wet season

VND stations	10	16	14	12	20	22	24	32	30	18	28	34	26	Total
Bottom salinity, °/oo	0.2	0.2	2.7	3.3	13.3	14.1	14.5	17.3	17.9	18.5	23.9	26.5	26.7	
Porifera (sponges)	0	0	0	0	0	0	0	0	0	0	0	1[a]	0	1
Coelenterata														
Hydrozoa (hydroids)	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Anthozoa (corals & anemones)														
Actinaria (anemones)	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Madreporaria (stony corals)	0	0	0	0	0	2	0	0	0	0	0	1	0	3
Annelida (worms)														
Polychaeta (bristleworms)														
Polynoidae	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Syllidae	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Nereidae	0	0	1	0	0	5	0	0	0	0	0	0	0	6
Goniadidae	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Eunicidae	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Orbiniidae	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Unknown family	0	4	0	0	0	0	0	0	0	0	0	0	0	4
Mollusca														
Gastropoda (snails)														
Mesogastropoda														
Cerithiidae (tide-flat shells)	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Cerithidea sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	1

[a] Fragments (considered as one individual)

Table XII, continued.

RUNG-SAT (defoliated) -- wet season - (cont'd.)

VND stations	10	16	14	12	20	22	24	32	30	13	28	34	26	Total
Bottom salinity, °/oo	0.2	0.2	2.7	3.3	13.3	14.1	14.5	17.3	17.9	18.[illegible]	23.9	26.5	26.7	
Calyptaeidae (cup & saucer shells)														
Calyptraea sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Crepidula sp.	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Naticidae (moon snails)	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Natica sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Bursidae (frog shells)														
cf. Bursa sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Neogastropoda														
Muricidae (rock shells)	0	0	0	0	0	0	6	0	0	0	0	0	0	6
Thais sp.	0	0	0	0	1	2	0	1	1	0	0	0	0	5
?Buccinidae (whelks)	0	0	0	0	0	0	0	0	1	0	0	0	0	1
?Mitridae (mitre shells)	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Pelecypoda (bivalves)														
Pteromorphia														
Arcidae (ark shells)														
Arca sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Anomiidae (jingle shells)														
Placuna placeota	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Ostreidae (oysters)	0	0	0	0	0	0	0	0	0	0	0	1	0	1
"dead shells"	0	0	0	0	0	0	0	0	0	0	1	0	8	9
Cephalopoda (squid & cuttlefishes)														
Sepioidea (cuttlefishes)	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Arthropoda														
Crustacea														
Malacostraca (crabs, lobster, shrimps)														
Stomatopoda (mantis shrimps)														
Squillidae														
Squilla sp. A	0	0	0	0	2	0	0	0	0	0	0	0	0	2

Table XII, continued.

RUNG-SAT (defoliated) -- wet season - (cont'd.)

VND stations	10	16	14	12	20	22	24	32	30	18	28	34	26	Total
Bottom salinity, °/oo	0.2	0.2	2.7	3.3	13.3	14.1	14.5	17.3	17.9	18.5	23.9	26.5	26.7	
Mysidacea (opossum shrimps)	0	0	0	0	3	0	0	0	2	4	0	0	0	9
Isopoda (peracarideans)														
Valvifera														
Idoteidae														
Idotea sp.	0	0	1	0	1	0	3	0	0	1	0	0	0	6
Amphipoda (beach fleas)														
Gammaridea	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Decapoda														
Natantia (true shrimps)														
Penaeidea														
Penaeidae														
Trachypenaeus sp.	0	0	0	0	0	0	0	0	0	0	0	0	4	4
?*Trachypenaeus* sp.	0	22	2	0	67	15	0	2	8	6	8	3	0	133
Unidentified genus	0	0	0	0	0	0	83	0	0	0	0	0	0	83
Sergestidae														
?*Acetes* sp.	0	0	2	1	11	1	10	0	51	372	0	0	1	449
Caridea (sand & snapping shrimps)														
Alpheidae (snapping shrimps)														
?*Alpheus* sp.	1	0	1	0	0	0	0	0	0	0	0	2[b]	1	5
Palaemonidae (prawns)														
?*Palaemontes* sp.	16	0	0	0	0	0	11[b]	0	0	4	0	0	0	31
Macrobrachium sp.	4[b]	10[b]	0	0	7[b]	9	4[b]	0	0	0	0	0	0	34
Reptantia (lobster, crayfish, crabs)														
Anomura (crabs)														
Diogenidae (hermit crabs)														
?*Clibanarius* sp. A	0	0	0	0	2	1	4	1	1	0	0	0	0	9
?*Clibanarius* sp. B	0	0	0	0	0	4	2	0	0	0	0	0	0	6

[b] Includes ovigerous specimens

Table XII, continued.

RUNG-SAT (defoliated) -- wet season - (cont'd.)

VND stations	10	16	14	12	20	22	24	32	30	18	28	34	26	Total
Bottom salinity, $^{o}/oo$	0.2	0.2	2.7	3.3	13.3	14.1	14.5	17.3	17.9	18.5	23.9	26.5	26.7	
Brachyura (true crabs)														
Portunidae (swimming crabs)														
?*Portunus* sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Charybdis sp.	0	0	0	0	0	1	1	0	0	0	0	0	1	3
Xanthidae (mud crabs)														
Unidentified genus	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Dorippidae														
Ethusa sp.	0	0	0	0	1	0	2	0	0	0	0	1	0	4
Leucosiidae														
?*Philyra* sp.	0	0	0	0	0	0	0	0	2	0	0	0	0	2
Sipunculida (peanutworms)	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Echinodermata														
Asteroidea (sea stars)														
Phanerozonia														
Luidiidae														
Luidia sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Ophiuroidea (brittlestars)														
Ophiurae														
Amphiuridae	0	0	0	0	0	1	1	0	0	0	0	0	0	2
Ophiactidae														
Ophiactis sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total specimens	21	38	7	1	98	45	129	4	68	388	12	13	20	844

Table XII, continued.

RUNG-SAT (defoliated) -- dry season

VND stations	66	64	62	60	80	74	72	68	78	70	76	Total
Bottom salinity, $^{o}/oo$	3.5	4.3	6.5	15.5	17.9	20.5	21.3	23.3	25.9	26.1	27.3	
Coelenterata												
Hydrozoa (hydroids)	0	0	0	1[a]	0	0	0	0	0	1[a]	0	2
Scyphozoa (medusae)	0	0	1	0	0	0	0	0	0	0	0	1
Anthozoa (corals & anemones)												
Madreporaria (stony corals)	0	0	0	0	0	0	0	0	0	0	3	3
Annelida (worms)												
Polychaeta (bristleworms)												
Eunicidae	0	0	0	0	0	0	0	0	0	0	4	4
?Orbiniidae	0	0	0	0	0	1	0	0	0	0	0	1
Sabellidae	0	0	240+	0	0	0	0	0	0	0	0	240+
Unknown family	0	0	3+	0	0	0	0	0	0	0	1	4+
Mollusca												
Gastropoda (snails)												
Neogastropoda												
Buccinidae (whelks)	0	0	1	0	0	0	0	0	0	0	0	1
Marginellidae (marginellas)												
Hyalina sp.	0	0	0	0	0	1	0	0	0	0	0	1
Pelecypoda (bivalves)												
Protobranchia												
Nuculidae (little nut shells)												
Nuculana sp.	0	0	0	0	0	1	0	0	0	0	1	2
Pteromorphia												
Mytilidae (mussels)	0	0	1	0	0	0	0	0	0	0	1	2
Heteroconchia												
Tellinidae (sunray clams)	0	0	0	0	0	1	0	0	0	0	0	1
Aloididae												
Corbula sp.	0	0	0	0	0	1	0	0	0	0	0	1

[a] Fragments (considered as one individual)

Table XII, continued.

RUNG-SAT (defoliated) -- dry season - (cont'd.)

VND stations	66	64	62	60	80	74	72	68	78	70	76	Total
Bottom salinity, °/oo	3.5	4.3	6.5	15.5	17.9	20.5	21.3	23.3	25.9	26.1	27.3	
Pholadidae (piddocks)												
Martesia sp.	0	0	0	0	0	0	0	0	0	0	1	1
Unknown order	0	0	0	0	0	0	0	0	0	0	1	1
Cephalopoda (squid & cuttlefishes)												
Sepioidea (cuttlefishes)												
Sepiidae												
Sepiella sp.	0	0	0	0	0	0	0	0	0	0	1	1
Arthropoda												
Crustacea												
Malacostraca (crabs, lobster, shrimps)												
Stomatopoda (mantis shrimps)												
Squillidae	0	0	0	0	0	0	0	0	0	1	0	1
Squilla ?quinquedentata	0	0	0	0	0	0	0	0	0	0	2	2
Squilla scorpio	0	0	0	0	1	0	0	0	0	0	0	1
Mysidacea (opossum shrimps)	0	6	8	3	0	0	0	2	1	0	0	20
Isopoda (peracarideans)												
Flabellifera (parasitic)												
Sphaeromidae												
?*Exosphaeroma* sp.	0	5	0	0	0	0	0	0	0	2	0	7
?*Cilicaea* sp.	0	0	0	0	0	0	0	0	0	0	1	1
Valvifera												
Idoteidae												
Cleantis sp.	0	0	0	0	0	1	0	2	0	0	0	3
Amphipoda (beach fleas)												
Gammaridea												
?Talitridae (beach fleas)	0	0	4	0	0	0	0	0	0	0	0	4
Corophiidae	0	1	0	0	0	0	0	0	0	0	0	1

Table XII, continued.

RUNG-SAT (defoliated) -- dry season - (cont'd.)

VND stations	66	64	62	60	80	74	72	68	78	70	76	Total
Bottom salinity, $^{o}/oo$	3.5	4.3	6.5	15.5	17.9	20.5	21.3	23.3	25.9	26.1	27.3	
Decapoda												
Natantia (true shrimps)												
Penaeidea												
Penaeidae												
?Trachypenaeus sp.	2	1	1	2	148	91	5	15	155	2	57	479
Unidentified genus	0	0	0	0	0	0	0	0	0	4	0	4
Sergestidae												
?Acetes sp.	1	312	233	353	100	16	346	261	57	298	111	2,088
Caridea (sand & snapping shrimps)												
Pasiphaeidae												
Leptochela sp.	0	0	0	0	0	0	0	0	0	0	3[b]	3
Alpheidae (snapping shrimps)												
?Alpheus sp.	0	1	3	0	0	0	0	0	0	0	1	5
Palaemonidae												
?Palaemon sp.	0	0	0	0	0	0	0	0	0	0	6[b]	6
?Leander sp.	0	0	0	0	2[b]	0	0	0	0	0	0	2
?Periclimenes sp.	0	0	0	0	0	0	0	0	2	0	3[b]	5
Macrobrachium sp.	0	0	51[b]	0	0	3[b]	0	0	0	0	0	54
Reptantia (lobster, crayfish, crabs)												
Anomura												
Porcellanidae (porcelain crabs)												
Unidentified genus	0	0	0	0	0	1	0	0	0	0	0	1
Diogenidae (hermit crabs)												
?Paguristes sp.	0	0	0	0	0	0	0	0	2	0	0	2
Unidentified genus sp. A	0	0	0	0	0	1	0	0	0	0	0	1
Unidentified genus sp. B	0	0	0	0	0	1	0	0	0	0	0	1

[b]Includes ovigerous specimens

Table XII, continued.

RUNG-SAT (defoliated) -- dry season - (cont'd.)

VND stations	66	64	62	60	80	74	72	68	78	70	76	Total
Bottom salinity, °/oo	3.5	4.3	6.5	15.5	17.9	20.5	21.3	23.3	25.9	26.1	27.3	
Brachyura (true crabs)												
Portunidae (swimming crabs)												
Charybdis ?*cruciata*	0	0	0	0	0	1	0	0	0	0	1	2
?*Lissocarcinus* sp.	0	0	0	0	0	1	0	0	0	0	0	1
Unidentified genus	0	0	0	0	1	0	0	0	0	0	0	1
Xanthidae (mud crabs)												
?*Leptodius* sp.	0	0	1	0	0	0	0	0	0	0	0	1
?*Sphaerozius* sp.	0	0	36[b]	0	0	0	0	0	0	0	0	36
Dorippidae												
Ethusa ?*sexdentata*	0	0	0	0	2	0	0	0	0	0	0	2
Ethusa sp.	0	0	0	0	0	4	0	0	1	0	0	5
Leucosiidae												
?*Philyra* sp.	0	0	0	0	0	1	0	0	0	0	0	1
Unidentified family	0	0	0	0	0	0	0	1	0	0	0	1
Bryozoa (moss animals)	0	0	0	0	0	0	0	1[a]	0	0	0	1
Echinodermata												
Asteroidea (sea stars)												
Phanerozonia												
Luidiidae												
Luidia sp.	0	0	0	0	0	0	0	0	1	0	0	1
Holothuroidea (sea cucumbers)	0	0	0	0	0	0	0	0	0	0	1	1
Chaetognatha (arrow-worms)	0	0	0	0	0	0	0	1	0	0	1	2
Total specimens	3	326	583+	359	254	126	351	283	219	308	200	3,012+

[a]Fragments (considered as one individual)
[b]Includes ovigerous specimens

Table XII, continued.

VUNG-TAU (nondefoliated) -- wet season

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, °/oo	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Porifera (sponges)	0	1[a]	1[a]	0	0	2[a]	0	0	0	2	2	0	8
Coelenterata													
Hydrozoa (hydroids)	0	1[a]	0	0	0	0	0	0	0	0	4	0	5
Scyphozoa (medusae)	0	0	0	0	0	0	0	0	0	0	1	0	1
Anthozoa (corals & anemones)													
Pennatulacea (sea pens)	0	0	1	0	0	0	0	0	1	0	0	0	2
Pteroeididae													
Pteroeides sp.	0	0	1	13	1	0	0	0	8	0	0	8	31
Actinaria (anemones)	0	0	0	0	0	0	0	0	0	2	1	2	5
Nemertea (nemertean worms)	2	1[a]	0	0	0	0	0	1[a]	0	1	0	0	5
Annelida (worms)													
Polychaeta (bristleworms)													
Polynoidae	0	10	0	0	0	0	0	0	0	0	0	0	10
?Polynoidae	0	0	0	0	0	0	0	2	0	1	0	0	3
Phyllodocidae	1	0	0	0	0	0	0	2	0	0	0	0	3
Hesionidae	0	3	0	0	0	0	0	1	0	0	4	0	8
Syllidae	0	1	0	0	0	0	0	0	0	0	0	0	1
Nereidae	0	2	0	0	0	0	0	1	0	3	1	0	7
Goniadidae	3	0	0	0	0	0	0	1	0	0	0	0	4
Onuphidae	0	0	0	0	0	0	0	10	0	0	0	0	10

[a] Fragments (considered as one individual)

Table XII, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, $^o/oo$	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Eunicidae	2	2	0	0	0	0	0	0	0	0	0	1	5
Lumbrineridae	2	0	0	0	0	0	0	0	0	0	0	0	2
Orbiniidae	0	0	0	0	0	0	0	1	0	0	0	0	1
Opheliidae	0	1	0	0	0	0	0	1	0	0	0	0	2
Sternaspidae	1	0	0	0	0	3	0	0	0	0	0	0	4
Pectenariidae	0	0	0	0	0	0	0	0	0	1	0	0	1
Ampharetidae	0	1	0	0	0	0	0	0	0	0	0	0	1
Terebellidae	0	3	0	0	0	0	0	8	0	2	0	0	13
Sabellidae	0	17	0	0	0	0	0	0	0	0	2	0	19
Unknown family	3	0	0	0	0	0	0	0	0	0	4	0	7
Mollusca													
Gastropoda (snails)													
Mesogastropoda													
Calyptaeidae (cup & saucer shells)													
Calyptraea sp.	0	0	0	0	0	0	0	0	0	0	0	1	1
Naticidae (moon snails)													
Natica sp.	0	0	0	0	0	0	0	0	0	0	0	2	2
Polynices didyma	0	0	0	0	0	0	0	0	0	0	0	1	1
Neogastropoda													
Muricidae (rock shells)													
Thais sp.	0	0	0	4	0	0	0	0	0	0	0	0	4
Murex sp.	0	0	0	0	0	0	0	0	0	0	0	1	1

Table XII, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, °/oo	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Mitridae (mitre shells)	6	0	0	0	0	0	0	0	0	4	0	0	10
?Mitridae	0	0	0	0	0	0	0	3	0	0	0	0	3
Volutidae (volutes)	0	0	0	1	0	0	0	0	0	0	0	0	1
Nudibranchia (sea slugs)	0	0	1	0	0	0	0	0	0	0	0	0	1
Unknown order	0	0	0	0	0	6	0	0	0	0	0	0	6
Scaphopoda (tooth shells)													
Dentaliidae	0	0	0	0	0	0	0	0	0	0	0	1	1
Pelecypoda (bivalves)													
Protobranchia													
Nuculidae (little nut shells)													
Nuculana sp.	0	0	0	0	0	3	0	2	0	6	0	0	11
Pteromorphia													
Arcidae (ark shells)	0	0	0	0	0	1	0	0	0	0	0	0	1
Arca sp.	0	0	0	1	0	0	0	0	0	2	0	0	3
Mytilidae (mussels)													
Brachydontes sp.	7	0	0	0	0	0	0	3	0	4	0	0	14
Limidae (file shells)													
Lima sp.	0	0	0	0	0	0	0	1	0	0	0	0	1
Anomiidae (jingle shells)													
Anomia sp.	0	0	0	0	0	0	0	0	0	0	0	3	3
Heteroconchia													
Semelidae													
?_Cumingia_ sp.	0	0	0	1	0	0	0	6	0	0	0	0	7
Solenidae (razor clams)	2	0	0	0	0	0	0	10	0	0	0	0	12
Pholadidae (piddocks)	0	0	1	0	0	0	0	0	0	0	0	0	1
Unknown order	0	0	0	0	0	0	0	?+	0	12	0	3	15+

Table XII, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, $^{o}/oo$	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
"dead shells"	0	0	0	3	0	0	0	0	0	0	0	0	3
Cephalopoda (squid & cuttlefishes)													
Sepioidea (cuttlefishes)	0	0	0	0	0	1	0	0	0	0	0	0	1
Sepiidae													
<u>Sepiella</u> sp.	0	0	0	1	0	0	0	0	0	0	0	0	1
Arthropoda													
Merostomata													
Xiphosura (horseshoe crabs)													
<u>Carcinocorpius</u> <u>rotundicauda</u>	1	0	0	0	0	0	1	0	0	0	0	0	2
Crustacea													
Cirrepedia (barnacles)													
Balanidae													
<u>Balanus</u> sp.	0	0	0	1	0	0	1	0	0	1	0	0	3
Malacostraca (crabs, lobster, shrimps)													
Stomatopoda (mantis shrimps)													
Squillidae													
<u>Squilla</u> <u>fasciata</u>	0	0	0	0	0	0	0	0	0	0	0	1	1
<u>Squilla</u> sp. A	0	0	0	0	0	0	0	0	0	0	1	0	1
<u>Squilla</u> sp. B	0	0	0	0	0	0	0	0	1	0	0	0	1
<u>Squilla</u> sp. C	0	0	0	0	0	0	3	0	0	0	0	0	3
Mysidacea (opossum shrimps)	20	5	0	31	0	0	4	19	0	32	15	1	127
Isopoda (peracarideans)													
Valvifera													
Idoteidae													
<u>Idotea</u> sp.	2	0	0	0	0	0	0	0	0	0	0	0	2
Epicaridea (parasitic)													
Bopyridae													
?<u>Bopyrina</u> sp.	0	0	0	0	0	0	0	1	0	0	0	0	1
<u>Orbione</u> sp.	0	0	0	1	0	0	0	0	0	0	0	0	1

Table XII, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, °/oo	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Amphipoda (beach fleas)													
Gammaridea	0	2	0	0	0	0	1	0	0	1	0	0	4
Decapoda													
Natantia (true shrimps)													
Penaeidea													
Penaeidae													
?*Trachypenaeus* sp.	119	2	12	21	15	105	35	111	17	8	3	10	458
Sergestidae													
?*Acetes* sp.	105	0	0	0	0	162	14	6	1	41	1	2	332
Caridea (sand & snapping shrimps)													
Alpheidae (snapping shrimps)													
?*Alpheus* sp.	6[b]	8[b]	7[b]	0	0	0	1	1	4	0	0	0	27
Palaemonidae													
Palaemonetes sp.	0	0	0	0	0	0	0	0	4[b]	0	0	0	4
?*Palaemonetes* sp.	13[b]	0	0	27[b]	0	0	3[b]	43[b]	0	3[b]	0	0	89
Macrobrachium sp.	0	1	0	0	0	0	0	0	0	0	0	0	1
Unidentified genus	0	0	0	0	0	0	0	0	1[b]	0	0	0	1
Reptantia (lobster, crayfish, crabs)													
Anomura													
Porcellanidae (porcelain crabs)													
Porcellana sp.	0	0	1[b]	13[b]	0	0	0	0	13[b]	0	0	7[b]	34
Unidentified genus	0	3	0	0	0	0	0	0	0	0	0	0	3
Diogenidae (hermit crabs)													
?*Clibanarius* sp. C	0	0	0	0	0	0	0	0	0	0	0	2[b]	2
Brachyura (true crabs)													
Portunidae (swimming crabs)													
?*Portunus* sp.	0	0	0	3[b]	0	0	0	0	1	0	0	3	7

[b] Includes ovigerous specimens

Table XII, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, °/oo	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Charybdis ?natator	0	0	0	0	0	0	10[b]	10	0	0	3	0	23
Charybdis sp.	0	0	0	17[b]	1	0	0	0	0	0	0	0	18
Scylla serrata	0	0	0	1	0	0	0	0	0	0	0	0	1
Podophthalamus sp.	0	0	0	1	0	0	0	0	0	0	0	0	1
Xanthidae (mud crabs)													
?_Myomenippe_ sp.	0	0	0	1	0	0	0	0	0	0	0	0	1
Unidentified genus	0	1	1	0	0	0	0	0	0	0	0	0	2
Majidae (spider crabs)													
Unidentified genus	0	0	0	1	0	0	1	0	0	0	0	0	2
Dorippidae													
Ethusa sp.	1	2	0	4	2	3	1	12	0	7	1	5[b]	38
Leucosiidae													
?_Philyra_ sp.	1	0	0	0	0	0	2	1	0	0	0	0	4
Unidentified family	0	0	0	2	0	1	0	10[b]	0	0	0	0	13
Sipunculida (peanutworms)	0	0	0	0	0	0	0	0	0	0	0	2	2
Echinodermata													
Ophiuroidea (brittlestars)													
Ophiurae													
Amphiuridae	1[a]	1	0	0	0	2	0	4	0	1	0	0	9
Ophiotrichidae	0	8	2	0	0	0	0	0	0	4	0	0	14
Echinoidea (sea urchins)													
Centrechinoidea													
Temnopleuridae													
Salmacis dussumieri	0	0	0	1	0	0	0	0	0	0	6	0	7

[a]Fragments (considered one individual)
[b]Includes ovigerous specimens

Table XII, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, $^{o}/oo$	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Holothuroidea (sea cucumbers)	0	23	1	2[a]	2	0	0	0	0	23	0	0	51
Chordata													
Ascidiacea (sea squirts)	0	2	0	0	0	0	0	0	0	2	0	0	4
Total specimens	298	99	29	151	21	289	77	271+	51	161	49	56	1,552+

[a]Fragments (considered as one individual)

Table XII, continued.

VUNG-TAU (nondefoliated) -- dry season

VND stations	100	84	104	82	86	90	88	102	92	98	94	96	Total
Bottom salinity, $^{o}/oo$	30.5	30.5	30.7	30.7	30.7	30.9	31.1	31.7	32.1	32.3	33.3	33.5	
Porifera (sponges)	0	0	0	4[a]	0	0	2	0	0	0	-	0	6
Coelenterata													
Hydrozoa (hydroids)	0	0	1	4	1	1+	1+	0	0	0	-	0	8+
Hydroida (hydrozoans)													
Sertulariidae	0	0	0	0	0			0	0	0	-	2	4+
Scyphozoa (medusae)	0	1	0	0	0	1	0	1	0	0	-	1	4
Anthozoa (corals & anemones)													
Telestacea													
Telestidae													
Telesto sp.	1	0	0	0	1	0	1	0	0	3	-	3	9
Gorgonacea (horny corals)													
Melitodidae													
Melitodes sp.	0	0	0	0	0	0	0	0	0	0	-	1	1
Pennatulacea (sea pens)	0	0	0	0	0	0	0	1[a]	0	0	-	0	1
Pteroceididae													
Pteroeides sp.	2	0	0	1	0	0	0	0	0	0	-	0	3
Actinaria (anemones)	1	0	0	0	0	0	0	0	0	0	-	1	2
Annelida (worms)													
Polychaeta (bristleworms)													
?Polynoidae	0	0	0	0	0	1[a]	19	0	0	0	-	0	20
Hesionidae	0	0	0	1	0	0	1	0	0	0	-	0	2
Nereidae	0	0	0	8	0	0	5	0	0	0	-	0	13
Eunicidae	0	4	0	2	1	0	2	0	0	0	-	0	9
Terebellidae	0	0	0	0	0	0	17	0	0	0	-	0	17
Unknown family	0	0	0	0	0	0	4	0	0	1[a]	-	0	5

[a] Fragments (considered as one individual)

Table XII, continued.

VUNG-TAU (nondefoliated) -- dry season - (cont'd.)

VND stations	100	84	104	82	86	90	88	102	92	96	94	96	Total
Bottom salinity, $^{o}/oo$	30.5	30.5	30.7	30.7	30.7	30.9	31.1	31.7	32.1	32.3	33.3	33.5	
Mollusca													
Gastropoda (snails)													
Archeogastropoda													
Trochidae (top shells)													
Euchelus sp.	0	0	0	0	0	0	1	0	0	0	-	0	1
Mesogastropoda													
Turritellidae													
Turitella bacillum	0	0	0	0	0	0	0	0	0	1	-	0	1
Lamellaridae	0	0	0	0	0	0	1	0	0	0	-	0	1
Neogastropoda													
Muricidae (rock shells)													
Murex ternispina	0	0	0	0	0	0	0	0	1	0	-	0	1
Columbellidae													
Anachis sp.	0	0	0	0	0	0	1	0	0	0	-	0	1
Fasciolariidae (tulip shells)													
Latirus sp.	0	0	0	0	0	0	0	0	0	0	-	1	1
Nudibranchia (sea slugs)	0	0	0	0	0	0	1	0	0	0	-	0	1
Pelecypoda (bivalves)													
Protobranchia													
Nuculidae (little nut shells)	0	0	0	1	0	0	0	0	0	0	-	0	1
Nucula sp.	0	0	0	0	0	0	1	1	0	0	-	0	2
Pteromorphia													
Arcidae (ark shells)	0	0	0	1	0	0	0	0	0	0	-	0	1
Anadara sp.	0	0	0	2	0	0	1	0	0	0	-	0	3
Mytilidae (mussels)	0	0	0	0	0	0	1	0	0	0	-	0	1
Pectinidae (scallops)	0	0	0	1	0	0	0	0	0	0	-	0	1
Limidae (file shells)													
Lima sp.	0	0	0	0	0	0	1	0	0	0	-	0	1

Table XII, continued.

VUNG-TAU (nondefoliated) -- dry season - (cont'd.)

VND stations	100	84	104	82	86	90	88	102	92	98	94	96	Total
Bottom salinity, $^{o}/oo$	30.5	30.5	30.7	30.7	30.7	30.9	31.1	31.7	32.1	32.3	33.3	33.5	
Anomiidae (jingle shells)													
Enigmonia sp.	0	1	0	0	0	0	0	0	0	0	-	0	1
Ostreidae (oysters)	0	0	0	0	0	0	1	0	0	0	-	0	1
Crassostrea sp.	0	0	0	0	0	0	1	0	0	0	-	0	1
Heteroconchia													
Veneridae (clams)													
Pitar sp.	0	1	0	0	0	0	0	0	0	0	-	0	1
Tellinidae (sunray clams)	0	0	0	0	0	0	1	0	0	0	-	0	1
Solenidar (razor clams)													
Solen sp.	0	1	0	0	0	0	0	0	0	0	-	0	1
Saxicavidae (boring clams)	0	0	0	0	0	0	1	0	0	0	-	0	1
Cephalopoda (squid & cuttlefishes)													
Teuthoidea (squid)	0	0	0	1	0	0	0	0	0	0	-	0	1
Sepioidea (cuttlefishes)													
Sepiidae													
Sepia sp.	0	0	0	1	0	0	0	0	0	0	-	0	1
Sepiella sp.	0	0	0	0	0	0	0	0	0	0	-	2	2
Arthropoda													
Crustacea													
Ostracoda (seed shrimps)	0	0	0	0	0	0	0	0	0	0	-	2	2
Cirrepedia (barnacles)													
Balanidae													
Balanus sp.	0	1	1	0	0	2	0	0	0	0	-	0	4
Malacostraca (crabs, lobster, shrimps)													
Stomatopoda (mantis shrimps)													
Squillidae	0	0	8	0	7	0	0	0	0	0	-	0	15
Squilla ?_quinquedentata_	0	0	0	1	0	4	0	0	0	0	-	0	5

Table XII, continued.

VUNG-TAU (nondefoliated) -- dry season - (cont'd.)

VND stations	100	84	104	82	86	90	88	102	92	98	94	96	Total
Bottom salinity, $^{o}/oo$	30.5	30.5	30.7	30.7	30.7	30.9	31.1	31.7	32.1	32.3	33.3	33.5	
Squilla scorpio	0	0	1	0	0	0	0	0	0	0	-	0	1
Squilla sp. A	0	0	0	0	0	0	0	0	0	0	-	1	1
Mysidacea (opossum shrimps)	0	8	6	20	57	30	744	0	1	0	-	15	881
Isopoda (peracarideans)													
Flabellifera (parasitic)													
Sphaeromidae													
?*Cilicaea* sp.	0	0	0	1	0	0	0	0	0	0	-	0	1
Epicaridea (parasitic)													
Bopyridae													
Epirenaeon sp.	0	0	0	0	0	0	1	0	0	0	-	0	1
Probopyrus sp.	0	1	0	0	0	0	0	0	0	0	-	0	1
Amphipoda (beach fleas)													
Gammaridea													
?Talitridae (beach fleas)	0	0	0	3	0	0	31	0	0	0	-	0	34
Corophiidae	0	6	0	13	14	0	1	0	0	0	-	0	34
Decapoda													
Natantia (true shrimps)													
Penaeidea													
Penaeidae													
?*Trachypenaeus* sp.	4	20	12	2	13	0	13	8	2	3	-	10	87
Sergestidae													
?*Acetes* sp.	0	1	10	0	0	1	23	1	2	2	-	384	424
Caridea (sand & snapping shrimps)													
Hippolytidae													
?*Lysmata* sp.	0	0	0	0	0	0	1	0	0	0	-	2	3
Alpheidae (snapping shrimps)													
?*Alpheus* sp.	0	1	0	2	0	0	4[b]	0	0	0	-	0	7

[b]Includes ovigerous specimens

Table XII, continued.

VUNG-TAU (nondefoliated) -- dry season - (cont'd.)

VND stations	100	84	104	82	86	90	88	102	92	98	94	96	Total
Bottom salinity, $^{o}/oo$	30.5	30.5	30.7	30.7	30.7	30.9	31.1	31.7	32.1	32.3	33.3	33.5	
Palaemonidae													
?*Leander* sp.	0	40[b]	6[b]	0	1	0	1	0	0	0	-	9[b]	57
Unidentified genus	1[b]	0	0	0	0	0	0	0	0	0	-	0	1
?Gnathophyllidae													
Unidentified genus	0	0	0	0	0	0	0	0	0	0	-	1	1
Reptantia (lobster, crayfish, crabs)													
Anomura													
Porcellanidae (porcelain crabs)													
Porcellana sp.	5[b]	0	0	2	0	0	4	0	0	0	-	1	12
?*Porcellana* sp.	0	0	0	0	24	2	0	0	0	0	-	0	26
?*Megalobrachium* sp.	0	0	0	0	0	0	1[b]	0	0	0	-	0	1
Brachyura (true crabs)													
Portunidae (swimming crabs)													
Portunus sp.	0	0	5	0	1	0	1	6	0	0	-	0	13
Charybdis ?*cruciata*	0	2	0	0	7	0	3	3[b]	7[b]	0	-	8[b]	30
?*Lissocarcinus* sp.	0	0	0	1	1	0	0	0	0	0	-	0	2
Scylla serrata	0	0	0	0	0	0	0	0	0	0	-	1	1
Unidentified genus	1	0	0	0	0	0	0	0	0	0	-	0	1
Xanthidae (mud crabs)													
?*Micropanope* sp.	0	0	0	0	0	1	47[b]	0	0	0	-	0	48
Unidentified genus	0	0	0	0	0	0	0	0	0	0	-	1	1
Majidae (spider crabs)													
Pugettia sp.	0	0	1	1	0	0	0	0	0	0	-	0	2
?*Hyastenus* sp.	0	0	0	0	0	0	0	0	0	0	-	1	1

[b] Includes ovigerous specimens

Table XII, continued.

VUNG-TAU (nondefoliated) -- dry season - (cont'd.)

VND stations	100	84	104	82	86	90	88	102	92	98	94	96	Total
Bottom salinity, $^{o}/oo$	30.5	30.5	30.7	30.7	30.7	30.9	31.1	31.7	32.1	32.3	33.3	33.5	
?*Maja* sp.	0	0	0	0	0	0	0	0	0	0	-	0	1
Dorippidae													
Dorippe ?*granulata*	1	0	0	0	0	0	0	0	0	0	-	0	1
Dorippe sp.	0	0	0	0	0	0	0	0	0	0	-	1	1
Ethusa sp.	0	2	0	5	0	0	1	2	1	0	-	0	11
Bryozoa (moss animals)	0	0	0	0	0	0	1[a]	1[a]	1[a]	0	-	0	3
Echinodermata													
Asteroidea (sea stars)													
Phanerozonia													
Luidiidae													
Luidia sp.	0	0	0	0	0	0	3	0	1	0	-	0	4
Ophiuroidea (brittle stars)													
Ophiurae													
Ophiotrichidae	0	3	0	3	0	0	14	0	0	0	-	2	22
Echinoidea (sea urchins)													
Centrechinoidea													
Temnopleuridae													
Salmacis dussumieri	0	0	0	0	0	0	0	0	0	0	-	1	1
Holothuroidea (sea urchins)													
Apoda													
Caudinidae													
?*Aphelodactyla* sp.	0	0	0	0	0	0	1	0	0	0	-	0	1
Chaetognatha (arrow-worms)	0	0	0	0	0	0	0	0	1	0	-	0	1
Chordata													
Ascidiacea (sea squirts)	0	1	0	0	0	0	2	0	1	0	-	0	4
Total specimens	16	93	51	81	128	44+	960+	24	17	10	-	452	1,876+

[a]Fragments (considered as one individual)

13 to 18^{o}/oo, mainly decapod shrimp, whereas their number greatly increased during the dry season, over a salinity range of about 4 to 27^{o}/oo. Crustaceans occurred at every station in the Vung-Tau Region. There is a greater diversity, as reflected in diversity indices of taxa, of animals in the Vung-Tau Region both during the wet season (2.21) and dry season (1.87) than in the wet season (1.69) and dry season (0.92) in the Rung-Sat Special Zone. Thus we may infer the Rung-Sat Special Zone represents an impoverished, stressed ecosystem, in contrast to the relatively rich invertebrate fauna in the Vung-Tau Region.

Because of the strong tidal currents in the Rung-Sat Special Zone as compared to the Vung-Tau Region, we might expect benthonic animals to experience more difficulty in finding an adequate habitat in which to hide or on which to hold in the Rung-Sat. However, because of the large amount of leaf, bark, and wood debris found along the estuarine bottom of the Rung-Sat Special Zone, we initially believed that large numbers of organisms might be found using this newly-made habitat for shelter. On the contrary, samples with greater amounts of debris usually had fewer organisms than did samples with less debris. Unfortunately, we were unable to quantify these data because of the difficulty in obtaining statistics on the area over which the trawl fished in both study areas. It is surmised that the large amounts of leaf, bark, and wood on the bottom of the Rung-Sat Special Zone represent a region inhospitable to many kinds of organisms because of the bacterial decomposition. This process would remove oxygen and could add toxic hydrogen sulfide to the interface between the bottom muds and the decomposing debris. Although we could not readily detect the smell of hydrogen sulfide in samples of debris, there was usually a distinct smell of decomposition, even though two years had passed since the defoliants were sprayed. A letter from Mr. Huynh-trung-Hat, Fishery Specialist for Vung-Tau City, to the Director of Fisheries, Saigon, stated:

> When the Allied Forces were spraying defoliants [1962-70], practically all the vegetation (approximately 95 percent) in Ban and Duoc mangroves were killed. As a result, the dead foliage caused the water to stink and the fauna (especially shrimp) to move to other areas.

Because we were probably unable to sample the oxygen content of the interface immediately between the bottom muds and the debris overlying them, it is not possible to show if low oxygen content might be a factor limiting the distribution and abundance of benthos in the Rung-Sat Special Zone.

Fishes. Juvenile and adult fishes were collected with a 10-ft bottom trawl (Table XIII). In the Rung-Sat Special Zone, 104 specimens of 29 species were taken in the wet season and 215 specimens of 17 species were caught in the dry season. Vung-Tau collections yielded 240 specimens of 34 species during the wet season, and 250 specimens comprising 22 species in the dry season. Diversity indices of fish families (Table XIV) show that the Rung-Sat Special Zone reflects the richest catches during the wet season, and the most impoverished fauna during the dry season, while the fish fauna of the Vung-Tau Region was intermediate, and remained similar during both seasons. Presumably the wide seasonal variation in diversity in the Rung-Sat Special Zone is due to seasonal salinity variation. If species diversity indices are examined (Table XV), the richest fish fauna occurred during the wet season in both study areas, with the Rung-Sat Special Zone having the

Table XIII.

Fishes collected with 10-ft otter trawl in mangrove region of SVN, 1972-73. Numbers in columns are numbers of specimens. The Rung-Sat is defoliated; Vung-Tau is nondefoliated (control) region. Wet season collections were made in October and November 1972. Dry season collections were made in January 1973. Dashes in columns indicate sample not collected.

RUNG-SAT (defoliated) -- wet season

VND stations	10	16	14	12	20	22	24	32	30	18	28	34	26	Total
Bottom salinity, $^{o}/oo$	0.2	0.2	2.7	3.3	13.3	14.1	14.5	17.3	17.9	18.5	23.9	26.5	26.7	
<u>Fishes</u>														
Dasyatidae (stingrays)														
<u>Dasyatis</u> ?<u>kuhlii</u>	0	0	0	0	0	0	1	0	0	0	0	0	0	1
<u>Urolophoides</u> sp.	0	0	0	0	2	1	0	0	0	0	0	0	0	3
Engraulidae (anchovies)														
<u>Coilia</u> <u>grayi</u>	0	0	0	0	1	0	0	0	0	4	0	0	0	5
Synodontidae (lizardfishes)														
<u>Harpodon</u> <u>nehereus</u>	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Ariidae (sea catfishes)														
<u>Arius</u> <u>macronotacanthus</u>	4	8	0	0	0	0	1	0	0	0	0	0	0	13
Plotosidae (catfish eels)														
<u>Plotosus</u> <u>canius</u>	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Polynemidae (threadfins)														
<u>Polynemus</u> <u>longipectoralis</u>	0	1	0	0	0	0	1	0	0	0	0	0	0	2
Apogonidae (cardinalfishes)														
<u>Apogon</u> <u>quadrifasciatus</u>	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Lutjanidae (snappers)														
<u>Lutjanus</u> <u>johni</u>	0	0	0	0	0	0	1	1	0	0	0	0	0	2
<u>Lutjanus</u> ?<u>johni</u>	0	0	0	0	1	0	0	0	0	0	0	0	0	1

Table XIII, continued.

RUNG-SAT (defoliated) -- wet season - (cont'd.)

VND stations	10	16	14	12	20	22	24	32	30	18	28	34	26	Total
Bottom salinity, $^{o}/oo$	0.2	0.2	2.7	3.3	13.3	14.1	14.5	17.3	17.9	18.5	23.9	26.5	26.7	
Fishes														
Leiognathidae (ponyfishes)														
Leiognathus berbis	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Leiognathus insidiator	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Gerreidae (mojarras)														
Gerres abbreviatus	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Pomadasyidae (grunts)														
Pomadasys hasta	0	0	0	0	0	0	0	1	0	0	1	0	0	2
Sciaenidae (croakers)														
?*Nibea acuta*	0	1	1	1	0	0	1	0	0	4	0	0	0	8
Pseudosciaena crocea	0	0	0	0	0	0	1	0	0	0	0	0	0	1
?*Wak sina*	0	0	0	0	10	13	7	0	1	0	4	0	0	35
Eleotridae (sleepers)														
Prionobutis koilomatodon	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Gobiidae (gobies)														
Acentrogobius caninus	0	0	0	0	0	0	0	1	0	0	0	0	1	2
?*Acentrogobius* sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Apocryptodon cf. *madurensis*	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Ctenogobius sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Glossogobius giurus	0	0	0	0	0	1	0	0	1	0	0	0	0	2
Trypauchen vagina	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Unidentified genus	0	0	0	0	0	1	0	0	0	0	0	0	0	1

Table XIII, continued.

RUNG-SAT (defoliated) -- wet season - (cont'd.)

VND stations	10	16	14	12	20	22	24	32	30	18	28	34	26	Total
Bottom salinity, $^{o}/oo$	0.2	0.2	2.7	3.3	13.3	14.1	14.5	17.3	17.9	18.5	23.9	26.5	26.7	
Fishes														
Cynoglossidae (tonguefish)														
Cynoglossus ?arel	0	0	0	0	3	0	0	0	0	0	0	0	0	3
Cynoglossus lingua	0	0	0	0	4	0	1	0	0	0	0	0	0	5
Soleidae (soles)														
Zebrias sp.	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Batrachoididae (toadfishes)														
Batrachus grunniens	1	0	0	0	0	1	0	0	0	0	0	0	0	2
Total specimens	5	15	1	1	22	18	16	3	2	8	9	0	4	104

Table XIII, continued.

RUNG-SAT (defoliated) -- dry season

VND stations	66	64	62	60	80	74	72	68	78	70	76	Total
Bottom salinity, $^{o}/oo$	3.5	4.3	6.5	15.5	17.9	20.5	21.3	23.3	25.9	26.1	27.3	
Fishes												
Clupeidae (herrings)												
?*Harengula ovalis*	0	0	0	0	0	0	0	1	0	0	0	1
?*Sardinella* sp.	0	0	0	1	0	0	0	0	1	0	1	3
Engraulidae (anchovies)												
Coilia grayi	0	1	2	0	3	7	7	3	3	1	1	28
Ariidae (sea catfishes)												
Arius macronotacanthus	1	0	9	0	0	1	0	0	6	0	0	17
Polynemidae (threadfins)												
Polynemus longipectoralis	0	1	1	0	0	0	0	0	0	0	0	2
Gerreidae (mojarras)												
Gerres filamentosus	0	0	0	0	0	0	0	0	0	0	1	1
Pomadasyidae (grunts)												
Pomadasys hasta	0	0	0	0	0	1	0	0	0	0	0	1
Sciaenidae (croakers)												
Pseudosciaena crocea	0	0	0	0	0	0	0	0	1	1	0	2
Sciaena russelli	0	0	0	0	0	1	0	0	0	0	1	2
?*Wak sina*	0	0	0	0	6	0	2	3	125	0	8	144
Gobiidae (gobies)												
Parachaeturichthys polynema	0	0	0	0	1	0	0	0	0	0	0	1
Trypauchen vagina	0	0	0	0	0	1	0	0	0	0	0	1
Unidentified genus	0	0	0	0	0	0	0	0	1	0	0	1

Table XIII, continued.

RUNG-SAT (defoliated) -- dry season - (cont'd.)

VND stations	66	64	62	60	80	74	72	68	78	70	76	Total
Bottom salinity, $^{o}/oo$	3.5	4.3	6.5	15.5	17.9	20.5	21.3	23.3	25.9	26.1	27.3	
Fishes												
Scorpaenidae (scorpionfishes)												
Leptosynaceia asteroblepa	0	0	0	0	0	1	1	0	0	0	0	2
Cynoglossidae (tonguefish)												
Cynoglossus brachycephalus	0	0	0	0	0	0	0	0	0	0	1	1
Cynoglossus lingua	0	0	0	0	1	6	0	0	0	0	0	7
Cynoglossus puncticeps	0	0	0	0	1	0	0	0	0	0	0	1
Total specimens	1	2	12	1	12	18	10	7	137	2	13	215

Table XIII, continued.

VUNG-TAU (nondefoliated) -- wet season

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, $^{o}/oo$	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Fishes													
Dasyatidae (stingrays)													
Dasyatis ?*kuhlii*	0	0	0	1	0	0	1	0	0	0	0	0	2
Centropomidae (snooks)													
Ambassis dayi	0	0	0	0	0	2	0	0	0	0	0	0	2
Apogonidae (cardinalfishes)													
Apogon quadrifasciatus	0	0	1	1	5	3	1	0	8	2	0	3	24
Sillaginidae (whitings)													
Sillago ?*sihama*	10	0	0	0	0	0	0	0	0	0	0	0	10
Sillago sp.	0	1	0	0	0	0	0	0	0	0	0	0	1
Lutjanidae (snappers)													
Lutjanus johni	1	1	1	0	3	0	0	0	0	0	0	0	6
Leiognathidae (ponyfishes)													
Leiognathus berbis	3	0	0	0	0	0	0	0	0	0	0	0	3
Leiognathus insidiator	8	0	0	0	0	1	0	0	0	0	0	0	9
Leiognathus ?*insidiator*	0	0	2	0	0	0	0	0	0	0	0	0	2
Pomadasyidae (grunts)													
Pomadasys hasta	13	2	0	1	1	12	0	4	0	3	0	1	37
Sciaenidae (croakers)													
Sciaena russelli	2	0	0	0	0	1	0	8	0	0	0	0	11
?*Wak sina*	0	0	0	4	1	0	3	0	0	1	3	0	12

Table XIII, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, °/oo	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Fishes													
Callionymidae (dragonets)													
Calliurichthys fluviatilis	0	0	0	0	0	0	0	0	0	0	0	2	2
Calliurichthys japonicus	3	0	0	0	0	7	0	4	1	0	0	0	15
Eleotridae (sleepers)													
Prionobutis koilomatodon	2	1	0	0	0	3	0	1	6	4	0	2	19
Gobiidae (gobies)													
Acentrogobius caninus	0	0	0	1	0	0	3	0	0	0	0	0	4
?*Acentrogobius triangularis*	0	0	0	0	0	6	0	0	0	0	0	0	6
Bathygobius fuscus	0	0	0	0	1	0	0	0	0	0	0	0	1
Bathygobius ?fuscus	0	0	0	0	0	0	0	1	0	0	0	0	1
?*Bathygobius fuscus*	0	0	0	1	0	0	0	0	0	0	0	0	1
Cryptocentrus russus	0	0	0	0	0	0	0	2	0	0	0	0	2
Glossogobius giurus	12	0	0	0	0	20	0	0	0	0	0	1	33
Trypauchen vagina	0	0	0	0	1	0	0	0	0	0	0	0	1
Unidentified genus	0	0	0	0	0	1	0	0	0	0	0	0	1
Scorpaenidae (scorpionfishes)													
Minous monodactylus	0	0	0	1	0	0	0	0	0	0	0	1	2

Table XIII, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

VND stations	42	44	40	46	48	56	58	50	38	52	54	36	Total
Bottom salinity, $^{0}/oo$	26.7	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.3	30.5	
Fishes													
Platycephalidae (flatheads)													
Grammoplites scaber	0	0	0	8	0	0	1	0	0	0	0	0	9
Bothidae (left-hand flounders)													
Arnoglossus tenuis	0	0	0	0	0	0	0	0	1	0	0	0	1
Cynoglossidae (tonguefish)													
Cynoglossus cf. brachycephalus	0	0	0	0	0	0	1	0	0	0	0	0	1
Cynoglossus macrolepidotus	0	0	0	0	0	0	1	0	0	0	0	0	1
Cynoglossus melampetalus	0	0	0	0	0	0	1	0	0	0	0	0	1
Cynoglossus puncticeps	1	0	0	0	0	0	0	2	0	0	0	0	3
Cynoglossus cf. puncticeps	0	0	0	0	0	0	0	0	0	1	0	0	1
Balistidae (filefishes & triggerfishes)													
Monacanthus nipponensis	0	0	0	0	1	0	0	1	1	0	0	0	3
Batrachoididae (toadfishes)													
Batrachus grunniens	0	0	0	11	1	0	0	0	0	1	0	0	13
Total specimens	55	5	4	29	14	56	12	23	17	12	3	10	240

Table XIII, continued.

VUNG-TAU (nondefoliated) -- dry season

VND stations	100	84	104	82	86	90	88	102	92	93	94	96	Total
Bottom salinity, $^{o}/oo$	30.5	30.5	30.7	30.7	30.7	30.9	31.1	31.7	32.1	32.[illegible]	33.3	33.5	
Fishes													
Clupeidae (herrings)													
?*Sardinella* sp.	9	0	0	0	0	0	0	0	0	0	-	0	9
Engraulidae (anchovies)													
Anchoviella ?*tri*	0	0	0	0	0	0	0	0	0	2	-	0	2
Polynemidae (threadfins)													
Polynemus sp.	0	0	0	0	0	0	0	0	0	0	-	1	1
Centropomidae (snooks)													
Ambassis dayi	0	0	0	0	0	0	0	0	0	0	-	1	1
Apogonidae (cardinalfishes)													
Apogon quadrifasciatus	0	0	0	1	0	0	0	5	0	0	-	0	6
Leiognathidae (ponyfishes)													
Leiognathus insidiator	7	4	0	0	0	1	0	0	1	1	-	0	14
Gerreidae (mojarras)													
Gerres filamentosus	2	1	1	0	0	0	0	1	0	0	-	0	5
Pomadasyidae (grunts)													
Pomadasys hasta	0	1	5	0	0	70	1	1	5	0	-	35	118
Sciaenidae (croakers)													
Argyrosomus aneus	0	0	0	0	0	0	0	0	1	0	-	0	1
Nibea ?*albiflora*	0	0	0	0	0	0	0	0	0	0	-	9	9
Sciaena russelli	0	0	0	0	0	1	0	0	0	1	-	0	2
?*Wak sina*	1	0	0	0	0	0	2	0	0	1	-	56	60

Table XIII, continued.

VUNG-TAU (nondefoliated) -- dry season - (cont'd.)

VND stations	100	84	104	82	86	90	88	102	92	9[illegible]	94	96	Total
Bottom salinity, $^{o}/oo$	30.5	30.5	30.7	30.7	30.7	30.9	31.1	31.7	32.1	32.3	33.3	33.5	
<u>Fishes</u>													
Callionymidae (dragonets)													
<u>Calliurichthys</u> ?<u>fluviatilis</u>	0	0	0	0	0	0	0	2	0	0	-	0	2
Eleotridae (sleepers)													
<u>Prionobutis</u> <u>koilomatodon</u>	0	2	0	1	0	0	0	0	0	0	-	0	3
Gobiidae (gobies)													
?<u>Acentrogobius</u> <u>caninus</u>	0	0	0	0	0	0	0	1	0	0	-	0	1
?<u>Cryptocentrus</u> cf. <u>russus</u>	0	6	0	0	0	0	0	0	0	0	-	0	6
Unidentified genus	1	0	1	0	0	0	0	0	0	0	-	1	3
Scorpaenidae (scorpionfishes)													
?<u>Prosopodasys</u> sp.	0	0	0	0	0	0	0	1	0	0	-	0	1
?<u>Minous</u> <u>monodactylus</u>	0	0	0	0	0	0	0	2	0	0	-	0	2
Platycephalidae (flatheads)													
<u>Grammoplites</u> <u>scaber</u>	0	0	0	0	0	0	0	0	1	0	-	1	2
Balistidae (filefishes & triggerfishes)													
<u>Monacanthus</u> <u>sulcatus</u>	0	0	0	0	0	0	0	1	0	0	-	0	1
Tetraodontidae (puffers)													
<u>Fugu</u> ?<u>ocellatus</u>	0	0	1	0	0	0	0	0	0	0	-	0	1
Total specimens	20	14	8	2	0	72	3	14	8	5	-	104	250

Table XIV.

Diversity indices of adult and juvenile fish families collected with bottom trawls in the estuaries of SVN. Stations are arranged in order of increasing salinity.

RUNG-SAT SPECIAL ZONE

VND stations	Wet season	Dry season
10	0.89	1.00
16	1.29	1.42
14	1.00	0.87
12	1.00	1.00
20	1.28	1.16
22	0.94	1.65
24	2.00	0.95
32	1.73	1.13
30	1.42	0.43
18	0.71	1.42
28	2.00	1.39
34	0.00	
26	1.50	
weighted average	1.67	0.68

VUNG-TAU REGION

VND stations	Wet season	Dry season
42	1.21	1.12
44	1.79	1.34
40	1.50	1.41
46	1.48	1.42
48	1.87	0.00
56	1.07	0.35
58	1.73	1.73
50	1.46	1.87
38	1.21	1.41
52	1.73	1.34
54	0.58	-[a]
36	1.90	0.59
weighted average	1.10	1.01

[a]Net did not fish properly

Table XV.

Diversity indices of adult and juvenile fish species collected with bottom trawls in the estuaries of SVN. Stations are arranged in order of increasing bottom salinity.

RUNG-SAT SPECIAL ZONE			VUNG-TAU REGION		
VND stations	Wet season	Dry season	VND stations	Wet season	Dry season
10	0.89	1.00	42	0.13	1.12
16	1.81	1.42	44	1.79	1.34
14	1.00	0.87	40	1.50	1.41
12	1.00	1.00	46	1.67	1.42
20	1.49	1.45	48	2.14	0.00
22	1.42	1.42	56	0.13	0.35
24	2.50	1.95	58	2.31	1.16
32	1.73	1.13	50	1.67	2.14
30	1.42	0.51	38	1.21	1.41
18	0.71	1.42	52	1.73	1.79
28	2.00	1.66	54	0.58	-[a]
34	0.00		36	1.90	0.69
26	1.50				
weighted average	2.84	1.16		2.19	1.39

[a] Net did not fish properly

greatest diversity of species. As with family diversity, species diversity was poorest in the Rung-Sat Special Zone during the dry season. The richness of the Rung-Sat fish fauna during the wet season probably reflects the wide salinity regime encountered here.

These differences in part show the occurrence of a larger number of fish families, and thus may reflect a greater variety of fishes appearing in waters of higher salinity, rather than a lessened productivity of the defoliated region during the dry season. This increase in number and variety of fishes is presumably related to the greater variety of habitats found in salt water, and to the fact that the nonestuarine environment is less severe in its physiological and ecological demands.

In this particular case, however, we must consider the difficulty encountered in properly collecting juvenile and adult fishes. Because of the swift tidal currents usually encountered in the Rung-Sat Special Zone, it was sometimes not possible to determine if the net was always fishing properly on the bottom, and hence a smaller catch might have been obtained. Conversely, the comparatively clearer waters of the Vung Tau Region might have permitted fishes to detect visually the oncoming net and thus avoid it, a factor that also would result in a smaller catch. Finally, many kinds of fishes, especially the larger or swift-swimming species, are not easily captured with a small bottom trawl of the type used in this study, necessitated by security and logistics. The only other type of sampling for large fishes entailed the use of MK3A2 hand grenades. Shallow, quiet-water embayments in both the Rung-Sat Special Zone and the Vung-Tau Region were frequently, though not statistically, sampled by grenades that were set to explode at the bottom or just beneath the sea surface. Although juvenile and adult fishes were frequently obtained in the Vung-Tau Region using grenades, dead fishes were never observed at the surface in the Rung-Sat Special Zone following the use of grenades. Only fishes possessing air bladders will float, and, while it was considered a priori that possibly fishes having gas bladders were uncommon in the Rung-Sat Special Zone, the trawl net in this zone frequently captured juvenile fishes of families possessing gas bladders. We thus interpret this to indicate a real lack of juvenile and adult fishes in the areas sampled by grenade in the Rung-Sat Special Zone.

Only on two occasions in the Rung-Sat Special Zone did we observe fishes swimming. We could not identify the species in one instance, while in the other, at the southernmost limit of the Rung-Sat Special Zone, we observed a stingray leaping from the water. Conversely, in the Vung-Tau Region we frequently saw schools of mullet, anchovies, herring, silversides, and halfbeaks swimming or jumping at the surface. This indicates not only the greater clarity of the water in the Vung-Tau Region, which permitted us to see the fishes, but also the greater biological diversity of that area.

Bird Life. Although none of the personnel involved in this study was a trained ornithologist, whenever possible we attempted to note the presence and activity of birds in both study areas. Generally speaking, the Rung-Sat Special Zone had a greater number of insect-eating birds such as swallows. Sandpipers were occasionally observed feeding along the banks. A few ospreys (piscivores) and sea eaglets were observed here as well. In the Vung-Tau Region there were also kingfishers, a stork, night herons, blue herons, terns, and gulls, in addition to the species observed in the Rung-Sat Special Zone. Birds were more frequently seen in the Vung-Tau Region and appeared to be more numerous. However, we were surprised at the relative lack of numbers and diversity of bird life along the beach and in the mangroves of the Vung-Tau Region in comparison with a somewhat similar yet larger and more speciose avifauna of South Florida.

The Food Web. The food and feeding relationships of organisms indicate interrelationships within an ecosystem (Odum 1971). Organisms are linked together by what they eat and what eats them. In a simple food chain, this relation tends to be linear, while in a more advanced ecosystem the interrelationships become complex webs of energy flow. Severe stress or rapid environmental changes involve reduction of the complex food web to simple forms involving only a few species (de Sylva 1973b).

To evaluate the food webs in the defoliated and nondefoliated areas, stomach contents of 323 juvenile and adult fishes were examined (Table XVI). These 46 species represent detritus feeders, planktivores, and primary, secondary, and tertiary carnivores feeding at all levels of the food web (Table XVII). Unfortunately, because our nets usually did not capture large fishes, knowledge of their food habits is limited. Nevertheless, juvenile and adult fishes of comparable size were caught in both study areas, and it appears reasonable to compare food webs of fishes of the same size in the two regions (Table XVIII).

Table XVI.

Number of stomachs containing food in fishes (2-28 cm) collected by 10-ft otter trawl in SVN. The Rung-Sat is defoliated; Vung-Tau is nondefoliated (control) region. Wet-season collections were made in October and November 1972. Dry-season collections were made in January 1973.

RUNG-SAT (defoliated) -- wet season

Fish species / Food item	Nematoda	Polychaeta	Gastropoda	Bivalvia	Crustacea (uniden.)	Copepoda	Isopoda	Amphipoda	Decapoda (uniden.)	Penaeidea	Caridea	Brachyura	Insecta Coleoptera	Ophiuroidea	Pisces	Algae or vegetable debris	Unidentified flesh	Mud or sand	Empty stomachs	Number of fish stomachs examined
Dasyatis ?kuhlii	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1
Urolophoides sp.	0	0	0	0	0	0	0	0	2	1	2	1	0	0	1	0	1	0	1	3
Coilia grayi	0	0	0	0	0	6	0	0	1	0	0	0	0	0	0	0	0	0	0	6
Harpodon nehereus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Arius macronotacanthus	3	7	0	0	0	2	2	1	2	0	2	2	1	1	0	1	3	0	0	12
Plotosus canius	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1
Polynemus longipectoralis	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	2
Lutjanus ?johni	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
Leiognathus berbis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Gerres abbreviatus	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pomadasys hasta	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
?Nibea acuta	1	0	0	1	0	3	1	2	3	0	0	2	0	0	0	1	1	0	1	5
Prionobutis koilomatodon	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Acentrogobius caninus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2

Table XVI, continued.

RUNG-SAT (defoliated) -- wet season - (cont'd.)

Food item / Fish species	Nematoda	Polychaeta	Gastropoda	Bivalvia	Crustacea (uniden.)	Copepoda	Isopoda	Amphipoda	Decapoda (uniden.)	Penaeidea	Caridea	Brachyura	Insecta Coleoptera	Ophiuroidea	Pisces	Algae or vegetable debris	Unidentified flesh	Mud or sand	Empty stomachs	Number of fish stomachs examined
Apocryptodon cf. madurensis	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	2
Ctenogobius sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Glossogobius giurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Trypauchen vagina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Cynoglossus ?arel	2	2	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	2
Cynoglossus lingua	2	1	0	2	2	1	0	0	1	0	0	1	0	2	1	1	0	1	0	4
Zebrias sp.	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Batrachus grunniens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Number of fish stomachs in which food items occurred	13	12	2	5	3	16	4	7	12	1	5	10	1	3	2	7	5	3	9	53

Table XVI, continued.

RUNG-SAT (defoliated) -- dry season

Fish species / Food items	Foraminifera	Porifera	Hydrozoa	Nematoda	Polychaeta	Oligochaeta	Gastropoda	Bivalvia	Copepoda	Stomatopoda	Isopoda	Amphipoda	Decapoda (uniden.)	Caridea	Anomura	Brachyura	Pisces	Mammalia	Algae or vegetable debris	Unidentified flesh	Eggs	Mud or sand	Empty stomachs	Number of fish stomachs examined
Coilia grayi	0	0	0	1	0	0	0	0	22	8	0	6	19	0	0	7[a]	0	0	0	0	0	0	1	24
Arius macronotacanthus	0	0	0	1	11	1	1	10	1	1	4	6	4	1	0	3	0	1	3	1	0	6	0	17
Polynemus longipectoralis	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Gerres filamentosus	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pseudosciaena crocea	0	0	0	0	0	0	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	2
Sciaena russelli	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
?Wak sina	1	1	2	18	16	0	0	2	14	0	1	69	36	0	1	2	2	0	20	8	1	0	5	90
Parachaeturichthys polynema	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Trypauchen vagina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Leptosynanceia asteroblepa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Cynoglossus brachycephalus	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1
Cynoglossus lingua	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0	0	1	0	0	0	1	4
Cynoglossus puncticeps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Number of fish stomachs in which food items occurred	1	1	2	20	28	1	1	14	43	11	5	86	62	1	1	12	2	1	24	10	1	6	11	147

[a] Including zoea

Table XVI, continued.

VUNG-TAU (nondefoliated) -- wet season

Fish species \ Food item	Foraminifera	Nematoda	Polychaeta	Gastropoda	Bivalvia	Crustacea (uniden.)	Ostracoda	Copepoda	Cirrepedia	Stomatopoda	Isopoda	Amphipoda	Decapoda (uniden.)	Caridea	Brachyura	Ophiuroidea	Pisces	Algae or vegetable debris	Unidentified flesh	Wood fragments	Shell fragments	Gravel	Mud or sand	Empty stomachs	Number of fish stomachs examined
Dasyatis ?kuhlii	0	0	1	0	0	0	0	1	0	0	0	2	2	0	1	0	0	0	0	0	0	0	0	0	2
Ambassis dayi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Apogon quadrifasciata	0	0	0	0	0	1	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	4
Sillago ?sihama	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1
Lutjanus ?johni	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	2	5
Pomadasys hasta	0	0	0	0	0	0	0	2	0	0	0	0	9	0	0	0	0	0	2	0	0	0	1	0	10
?Wak sina	0	3	1	0	0	0	0	3	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	1	4
Sciaena russelli	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1
Scatophagus argus	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1
Calliurichthys ?fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Prionobutis koilomatodon	0	2	2	0	0	1	2	3	2	0	1	3	5	2	0	2	1	6	0	0	0	0	1	2	16
Acentrogobius caninus	0	3	1	1	0	0	0	1	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	1	4
Bathygobius fuscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Glossogobius giurus	0	0	1	0	0	0	0	3	0	0	0	5	12	0	0	0	1	0	0	1	0	0	1	7	23
Grammoplites scaber	0	0	0	0	0	0	0	1	0	0	0	0	8	0	0	0	0	0	2	0	0	1	1	0	8

Table XVI, continued.

VUNG-TAU (nondefoliated) -- wet season - (cont'd.)

Food item	Foraminifera	Nematoda	Polychaeta	Gastropoda	Bivalvia	Crustacea (uniden.)	Ostracoda	Copepoda	Cirrepedia	Stomatopoda	Isopoda	Amphipoda	Decapoda (uniden.)	Caridea	Brachyura	Ophiuroidea	Pisces	Algae or vegetable debris	Unidentified flesh	Wood fragments	Shell fragments	Gravel	Mud or sand	Empty stomachs	Number of fish stomachs examined
Fish species																									
Arnoglosus tenuis	0	0	0	0	0	0	0	0	0	0	0	0	0	2[b]	0	0	0	0	0	0	0	0	0	0	1
Cynoglossus cf. brachycephalus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Cynoglossus macrolepidotus	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cynoglossus puncticeps	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2
Cynoglossus cf. puncticeps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1
Batrachus grunniens	1	4	0	1	2	0	0	0	0	1	0	0	1	2	10	1	0	2	0	1	0	0	4	2	13
Number of fish stomachs in which food items occurred	1	13	8	2	4	3	3	18	2	1	1	12	45	7	11	5	2	14	6	2	1	1	9	20	101

[b] Including larvae

Table XVI, continued.

VUNG-TAU (nondefoliated) -- dry season

Fish species / Food item	Polychaeta	Gastropoda	Bivalvia	Crustacea (uniden.)	Copepoda	Stomatopoda	Amphipoda	Decapoda (uniden.)	Caridea	Brachyura	Ophiuroidea	Pisces	Unidentified flesh	Empty stomachs	Number of fish stomachs examined
Anchoviella ?tri	0	1	0	0	1	0	0	2	0	2[a]	0	0	0	0	2
Apogon quadrifasciata	0	0	0	0	1	0	0	2	0	0	0	1	0	3	6
Leiognathus insidiator	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Gerres filamentosus	2	0	0	0	3	0	3	1	0	0	0	0	0	0	4
Pomadasys hasta	0	0	0	0	1	0	2	1	0	0	0	0	0	1	3
Argyrosomus aneus	0	0	0	0	1	0	1	1	0	0	0	0	0	0	1
Nibea ?albiflora	0	0	0	2	4	0	3	0	0	0	1	0	2	0	5
Sciaena russelli	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
?Wak sina	0	0	0	0	2	0	1	3	1	2[a]	0	0	0	1	6
Calliurichthys ?fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Prionobutis koilomatodon	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1
Grammoplites scaber	0	0	0	0	0	1	0	0	2	0	0	0	0	0	2
Monacanthus sulcatus	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1
Fugu ?ocellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
															37
Number of fish stomachs in which food items occurred	2	1	1	2	16	1	11	11	3	4	1	1	3	8	

[a] Including zoea

Table XVII.

Food habits of fishes in estuaries of SVN.

	Rung-Sat (defoliated)				Vung-Tau (nondefoliated)			
	1972 wet season		1973 dry season		1972 wet season		1973 dry season	
	No.	%	No.	%	No.	%	No.	%
Foraminifera	0	0	1	1	1	1	0	0
Sponges	0	0	1	1	0	0	0	0
Hydrozoans	0	0	2	1	0	0	0	0
Nematodes	12	29	20	13	10	10	3	9
Polychaetes	11	26	29	19	7	7	4	11
Oligochaetes	1	2	0	0	0	0	0	0
Gastropods	2	5	1	1	2	2	1	3
Bivalves	3	7	13	9	3	3	1	3
Crustacean uniden.	1	2	0	0	3	3	2	6
Ostracods	2	5	0	0	3	3	0	0
Copepods	16	38	43	29	15	16	16	46
Cirrepedes	0	0	0	0	2	2	0	0
Stomatopods	0	0	12	8	1	1	1	3
Isopods	4	10	5	3	1	1	0	0
Amphipods	8	19	86	58	14	15	8	23
Decapods	11	26	65	44	42	44	12	34

Table XVII, continued.

	Rung-Sat (defoliated)				Vung-Tau (nondefoliated)			
	1972 wet season		1973 dry season		1972 wet season		1973 dry season	
	No.	%	No.	%	No.	%	No.	%
Peneids	1	2	0	0	0	0	0	0
Carideans	5	12	1	1	6	6	3	9
Anomura	0	0	1	1	0	0	0	0
Brachyura	7	17	13	9	11	11	3	9
Insects	1	2	0	0	0	0	0	0
Ophiurians	1	2	0	0	3	3	3	9
Fishes	1	2	2	1	2	2	1	3
Mammals	0	0	1	1	0	0	0	0
Algae	6	14	23	15	14	15	0	0
Unidentified flesh	5	12	10	7	6	6	3	9
Eggs	0	0	1	1	0	0	0	0
Wood	0	0	0	0	2	2	0	0
Shell	0	0	0	0	1	1	0	0
Gravel	0	0	0	0	1	1	0	0
Mud or sand	2	5	6	4	9	9	0	0
Empty	5	12	10	7	19	20	8	23
Total examined	42		150		96		35	

Table XVIII.

Lengths of fishes collected with 10-ft otter trawl (in mangrove region of SVN, 1972-73), which were examined for stomach contents. Lengths are fork lengths, except for *Arnoglossus* and *Cynoglossus*, for which total length was used. Size of *Dasyatis* and *Urolophoides* is disk width.

Fish length (cm)	2-2.9	3-3.9	4-4.9	5-5.9	6-6.9	7-7.9	8-8.9	9-9.9	10-10.9	11-11.9	12-12.9	13-13.9	14-14.9	15-15.9	16-16.9	17-17.9	22-22.9	23-23.9	24-24.9	27-27.9	Total
Fishes examined																					
Dasyatis ?kuhlii	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	3
Urolophoides sp.	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	5
Anchoviella ?tri	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Coilia grayi	0	0	0	0	1	1	3	1	4	13	4	1	2	0	0	0	0	0	0	0	30
Harpodon nehereus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Arius macronotacanthus	0	0	3	1	5	5	4	1	0	2	1	1	2	1	1	0	0	1	0	0	28
Plotosus canius	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Polynemus longipectoralis	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Ambassis dayi	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Apogon quadrifasciata	0	3	1	1	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Sillago ?sihama	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lutjanus ?johni	0	4	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Leiognathus berbis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Leiognathus insidiator	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Gerres abbreviatus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gerres filamentosus	0	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7

Table XVIII, continued.

Fish length (cm)	2-2.9	3-3.9	4-4.9	5-5.9	6-6.9	7-7.9	8-8.9	9-9.9	10-10.9	11-11.9	12-12.9	13-13.9	14-14.9	15-15.9	16-16.9	17-17.9	22-22.9	23-23.9	24-24.9	27-27.9	Total
Fishes examined																					
Pomadasys hasta	2	7	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	12
Argyrosomus aneus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nibea ?albiflora	0	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
?Nibea acuta	1	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	6
Pseudosciaena crocea	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sciaena russelli	1	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4
?Wak sina	2	16	17	14	18	14	10	6	0	2	0	1	0	1	0	0	0	0	0	0	101
Scatophagus argus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Calliurichthys fluviatilis	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Calliurichthys ?fluviatilis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Prionobutis koilomatodon	2	7	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
Acentrogobius caninus	1	1	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Apocryptodon cf. madurensis	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Bathygobius fuscus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ctenogobius sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Glossogobius giurus	0	8	7	4	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	23
Parachaeturichthys polynema	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table XVIII, continued.

Fish length (cm)	2-2.9	3-3.9	4-4.9	5-5.9	6-6.9	7-7.9	8-8.9	9.9.9	10-10.9	11-11.9	12-12.9	13-13.9	14-14.9	15-15.9	16-16.9	17-17.9	22-22.9	23-23.9	24-24.9	27-27.9	Total
Fish examined																					
Trypauchen vagina	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Leptosynaceia asteroblepa	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Grammoplites scaber	0	0	0	0	3	1	0	0	0	3	1	0	0	0	0	2	1	0	0	0	11
Arnoglossus tenuis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cynoglossus ?arel	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Cynoglossus brachycephalus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cynoglossus cf. brachycephalus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cynoglossus lingua	0	1	0	0	0	2	2	0	2	0	0	0	0	0	0	0	1	0	1	0	9
Cynoglossus macrolepidotus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cynoglossus puncticeps	0	0	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4
Cynoglossus cf. puncticeps	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Zebrias sp.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Monacanthus sulcatus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Fugu ?ocellatus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Batrachus grunniens	0	0	0	5	1	5	0	1	0	0	0	1	1	0	1	0	0	0	0	0	15
Total specimens	10	63	47	42	45	37	27	15	8	22	6	4	6	3	3	2	2	1	1	1	345

During the wet season of the Vung-Tau Region (Figure 6), the food web is reasonably complex, showing several energy pathways and trophic levels that include secondary carnivores such as the flathead and the grunt. Detritus--an indication of a healthy, diverse ecosystem--is the prime source of energy. During the dry season (Figure 7), the pathways and relationships among the organisms are similar, but phytoplankton is believed to be an additional energy source, as evidenced by large quantities of planktonic copepods in surface waters.

In contrast the food web of the Rung-Sat Special Zone during the wet season is simple (Figure 8). In spite of the devastation of mangroves and the expected large amounts of detritus accumulating at the bottom of the estuaries, the strong tidal currents remove much wood, stems, and leaves of dead mangroves from these waters before they can decompose to organic detritus, and thus this energy is largely unavailable as a food source. Undoubtedly, however, the detritus is carried farther downstream where it is used for food in the littoral zone. During both the wet and dry seasons, high water turbidity in the Rung-Sat Special Zone probably reduces photosynthesis. Although diatoms occurred in both areas, they were far more abundant in the Vung-Tau Region, where turbidity is less (Table IV). During the dry season of the Rung-Sat Special Zone (Figure 9), a more complex and diverse food web is apparent, similar to that of the Vung-Tau Region during the dry season, except that detritus is the major energy source in the Rung-Sat Special Zone during the dry season. With less runoff and higher salinities during the dry season,

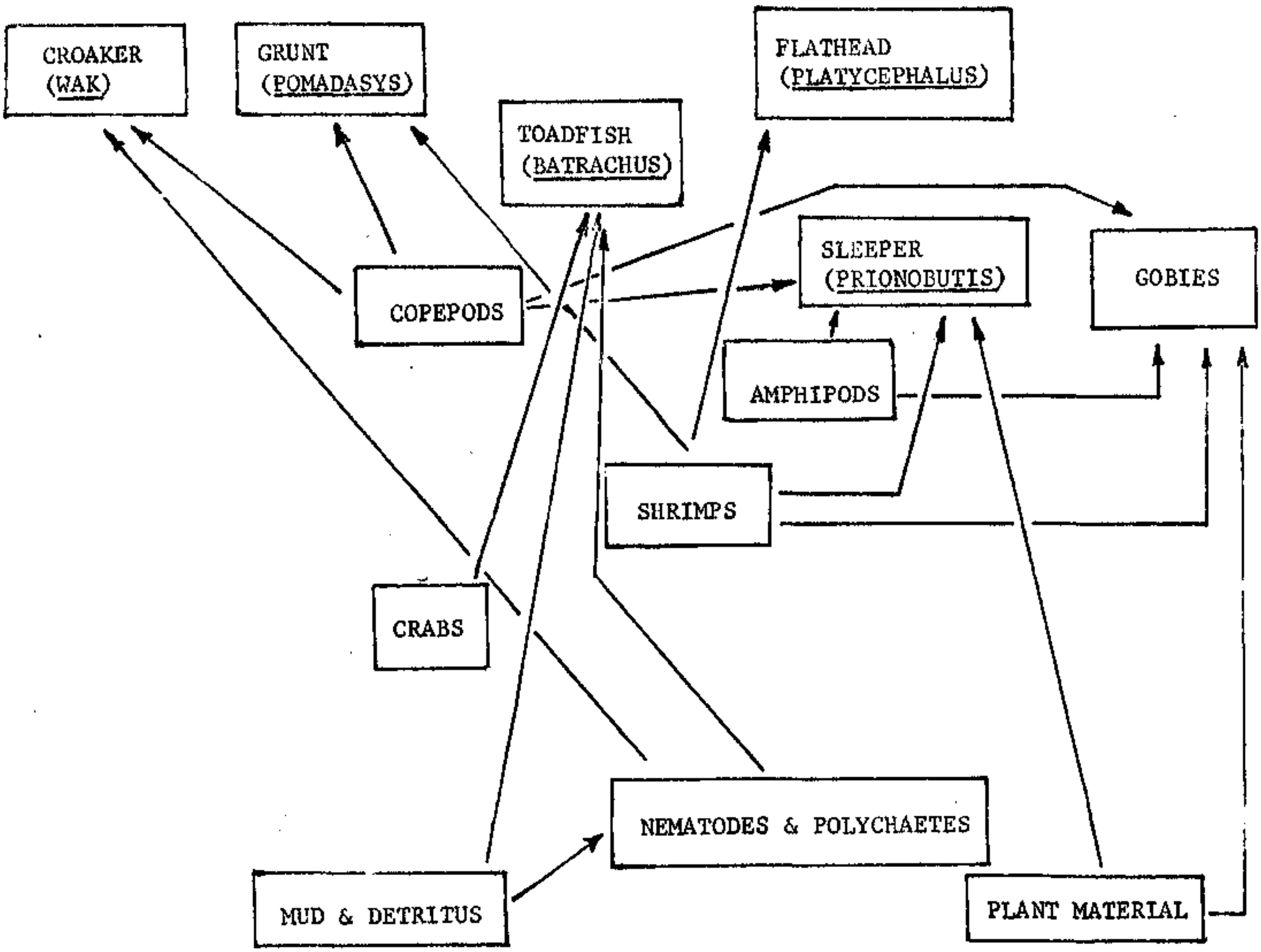

FIG. 6. Food web in nondefoliated estuary, Vung-Tau, SVN, wet season.

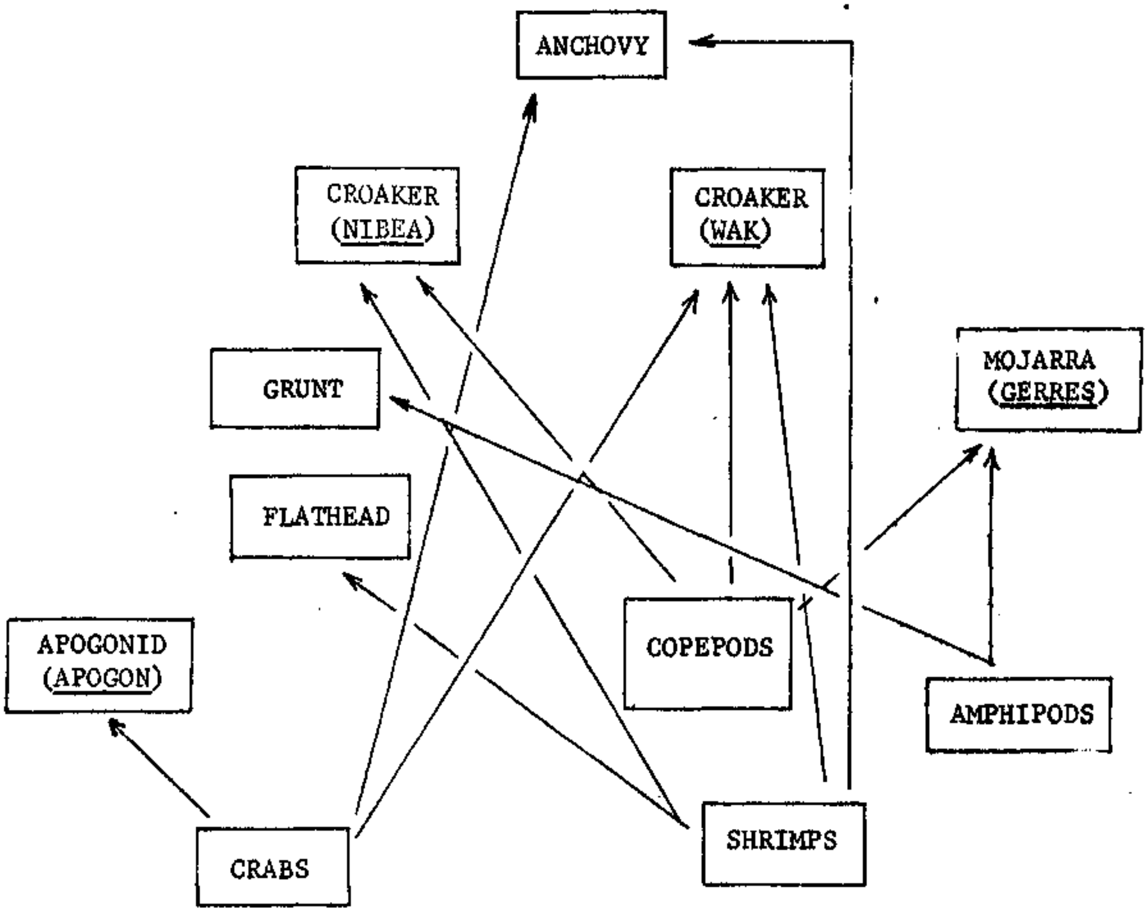

FIG. 7. Food web in nondefoliated estuary, Vung-Tau, SVN, dry season.

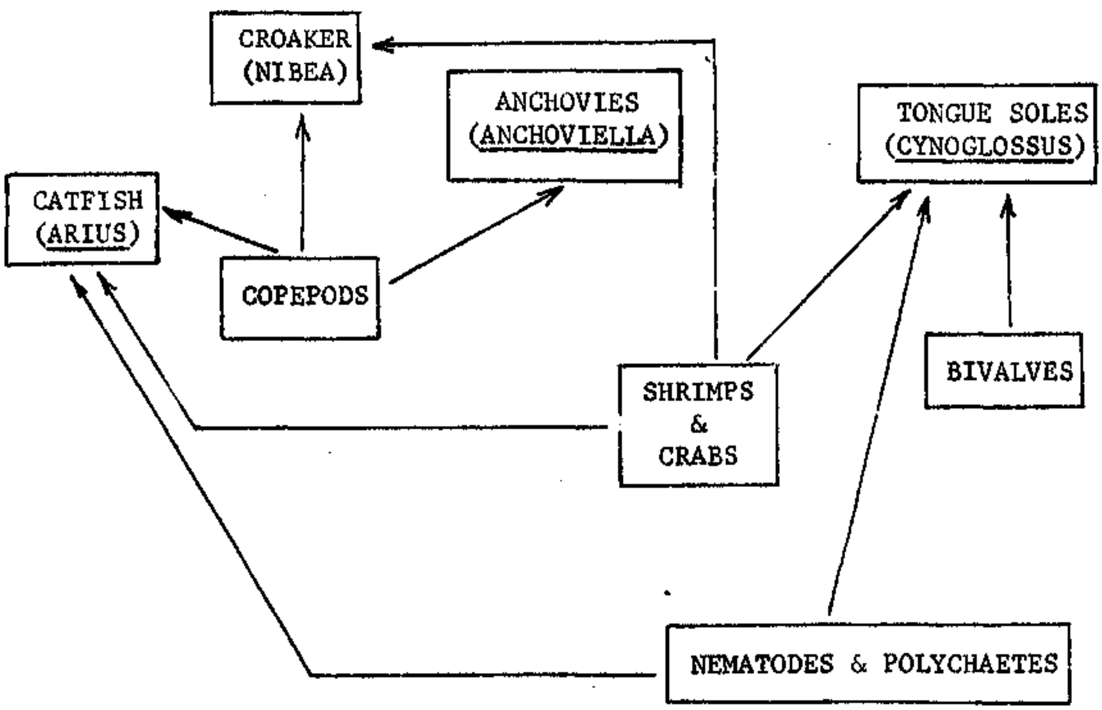

FIG. 8. Food web in defoliated estuary, Rung-Sat Special Zone, SVN, wet season.

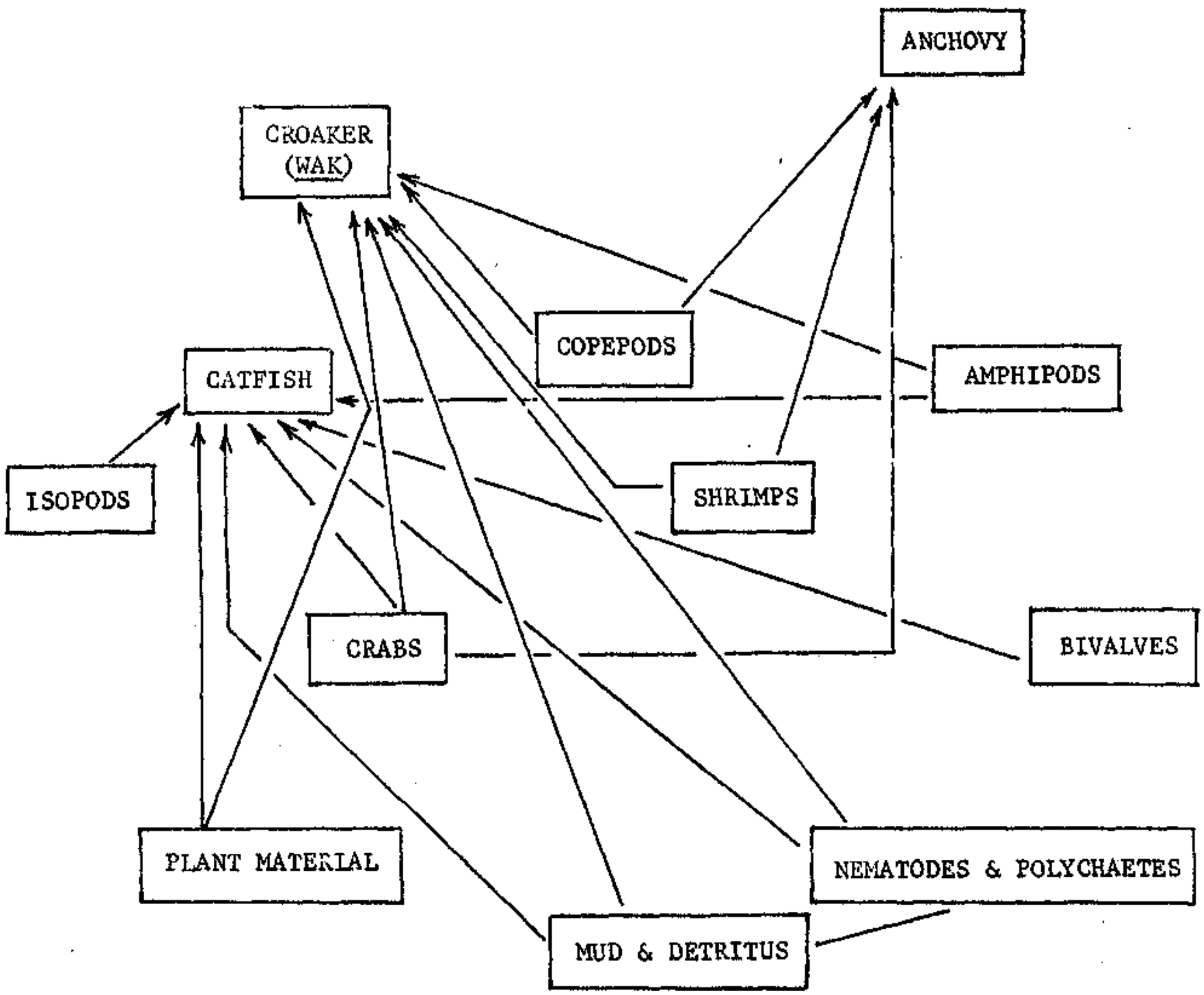

FIG. 9. Food web in defoliated estuary, Rung-Sat Special Zone, SVN, dry season.

a greater variety of organisms can invade the defoliated estuarine region and serve as food for predators. Yet secondary carnivores are scarce during both seasons, and probably reflect the stress ecosystem of the Rung-Sat.

There is no background data on food webs in Indochina. Since the country has been more or less continually at war since 1941, certainly many factors have affected the entire ecosystem. A hypothetical food web is depicted (Figure 10) that postulates energy pathways of man-made effects or war-related activities. The waters of the Saigon River, especially between Saigon and Nha-Be, contain a melange of sewage and industrial wastes, insecticides, paints, solvents, a variety of war materiel, explosives, chemicals, and waste products from hospitals flooded with war casualties. Along the river banks, war-time activities include, in addition to a variety of herbicides, the effects of napalm upon soils and vegetation, laterized soils from defoliation or Rome plowing, and rusting military hardware. We can only speculate upon the total effect of this combined effluent into the Rung-Sat Special Zone farther downstream.

The Commercial Marine Fisheries of Vietnam

The Vietnamese rely heavily upon aquatic life for food, with 80 to 90 percent of their protein coming from fish. Marine fish, crustaceans, and mollusks comprised 77 percent of the total fishery catch of Vietnam in 1969 (Brouillard 1970). That fishing is an important part of the Vietnamese economy is well documented (Soulier 1963, Loftas 1970).

During our studies in Vietnam, we were unable to participate in any

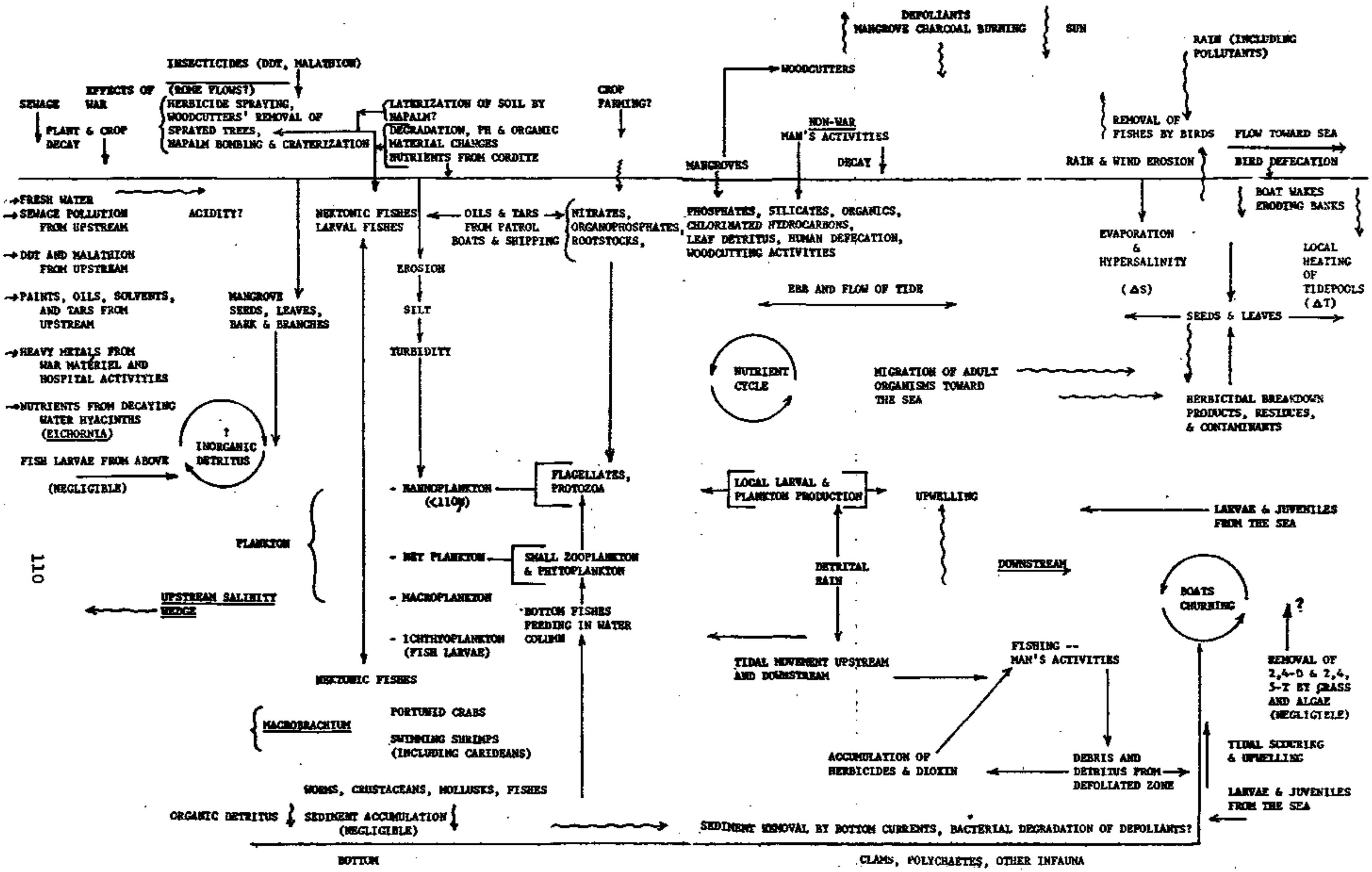

FIG. 10. Hypothetical energy pathways in the Rung-Sat estuaries, SVN, 1972.

trips aboard fishing vessels of any type. Frequent visits were made to fish markets around Saigon and at Vung-Tau and Xa-Thang, near Vung-Tau, to determine which species of fishes and invertebrates were commercially important. Some species were purchased for subsequent identification.

No major fishing activity was seen in the Rung-Sat Special Zone, probably because security still posed a problem, but possibly because this area is not (or perhaps never has been) a rich fishing area. Small boats were occasionally seen using a 2-poled dip net (luoi dan), which pushed ahead of the boat. Presumably these nets catch anchovies, but we were not able to examine the catch. In the Vung-Tau Region, on the contrary, many such dip-net boats were observed. Common in this region are stake nets, which consist of numerous poles driven into the bottom, from which nets are strung. Fishes are enmeshed as they move with the tides, and are subsequently removed by the fishermen at the end of each tidal cycle. Also common were boats fishing drift gill nets and bottom set lines. Farther offshore, larger vessels used set lines, drift nets, shrimp trawls, and long gill nets.

Little detailed information is available on the number of pounds of shellfish (shrimps, crabs, oysters, clams) and marine fishes caught by commercial fishermen in SVN. Brouillard (1970) presented data on the marine fish catch of SVN from 1963 to 1969. It shows a gradual increase of from just under 3 million metric tons in 1963 to about 5 million metric tons in 1969 (Table XIX). This merely may indicate that the number of persons and boats fishing has increased.

Table XIX.

Catch (metric tons), number of trawlers, and catch per unit of effort in the South China Sea and the Gulf of Thailand, 1952-1970. Data from Brouillard (1970) and Shindo (1973).

	Vietnamese vessels, coastal South Viet Nam			Japanese trawlers, South China Sea			Taiwanese trawlers, South China Sea			Thai trawlers, Gulf of Thailand		
	catch, tons x 10^3	trawlers	effort	catch, tons	no. trawlers	effort	catch, tons	no. baby trawlers	effort[b]	catch, tons x 10^3	no. trawlers	effort
1952	-	-[a]	-	3,079	14	219	-	-	-	-	-	-
1953	-	-	-	11,730	30	391	-	-	-	-	-	-
1954	-	-	-	12,045	31	388	2,214	468	4.3	-	-	-
1955	-	-	-	8,171	23	355	2,623	558	7.8	-	-	-
1956	-	-	-	8,389	30	279	3,657	685	7.8	-	-	-
1957	-	-	-	10,283	29	354	4,802	867	6.9	-	-	-
1958	-	-	-	16,461	74	222	4,837	862	7.6	-	-	-
1959	-	-	-	8,155	23	354	5,518	918	8.8	-	-	-
1960	-	-	-	5,647	14	403	6,040	962	9.1	-	-	-
1961	-	-	-	1,007	10	101	7,122	1,044	9.1	123	201	612
1962	-	-	-	384	4	96	6,984	964	12.7	151	976	155
1963	299	9,220	32	166	2	83	8,529	1,195	14.2	277	2,026	136
1964	314	9,710	32	0	0	0	11,905	1,386	15.5	372	2,360	158
1965	289	12,240	24	0	0	0	13,666	1,501	20.8	393	2,396	282
1966	287	16,770	17	0	0	0	16,857	1,756	28.2	449	2,695	166
1967	319	23,195	14	0	0	0	23,310	1,979	32.0	583	3,077	189
1968	321	29,968	11	0	0	0	30,061	2,374	29.1	784	3,182	247
1969	355	39,001	9	0	0	0	32,886	2,278	33.9	908	3,185	285
1970	-	-	-	0	0	0	34,751	2,129	40.8	-	3,114	-

[a] data not available

[b] annual total per gross ton

A more meaningful analysis can be made if the number of motorized fishing vessels is considered as units of fishing gear, and these are divided each year into the marine fish catch for that year, giving a rough index of catch per unit of fishing effort (Figure 11). This catch curve indicates that the catch per unit of effort for marine fish species has steadily decreased, and shows a classic picture of a fishery that is steadily disappearing.

Historically, Japanese trawlers working in the South China Sea experienced considerable fluctuations in catch per effort (Shindo 1973). Between 1960 and 1961, the catch and catch per effort dropped drastically, indicating that overfishing by these vessels was already occurring. According to Shindo,

> After 1958, the number of Japanese trawlers operating in the South China Sea would have increased rapidly, but the escalation of the war in Viet Nam prevented this development. Moreover, the decline of the catch rate in these waters made them less attractive. Hence the fishing operations ceased in 1963.

Because Thai trawlers fishing in the Gulf of Thailand are probably fishing many of the same racial stocks as occur in the South China Sea, a remarkably parallel drop in catch per effort of Thai trawlers is not unexpected.

It seems likely that Japanese trawlers were at least partly responsible for the abrupt decline in catch after 1960. The rate of decrease in catch per effort of Vietnamese trawlers is quite similar. With the cessation of extensive Japanese trawling operations, it would be expected that the Vietnamese catch per effort would have increased or at least stabilized if no factors other than fishing were operative. However,

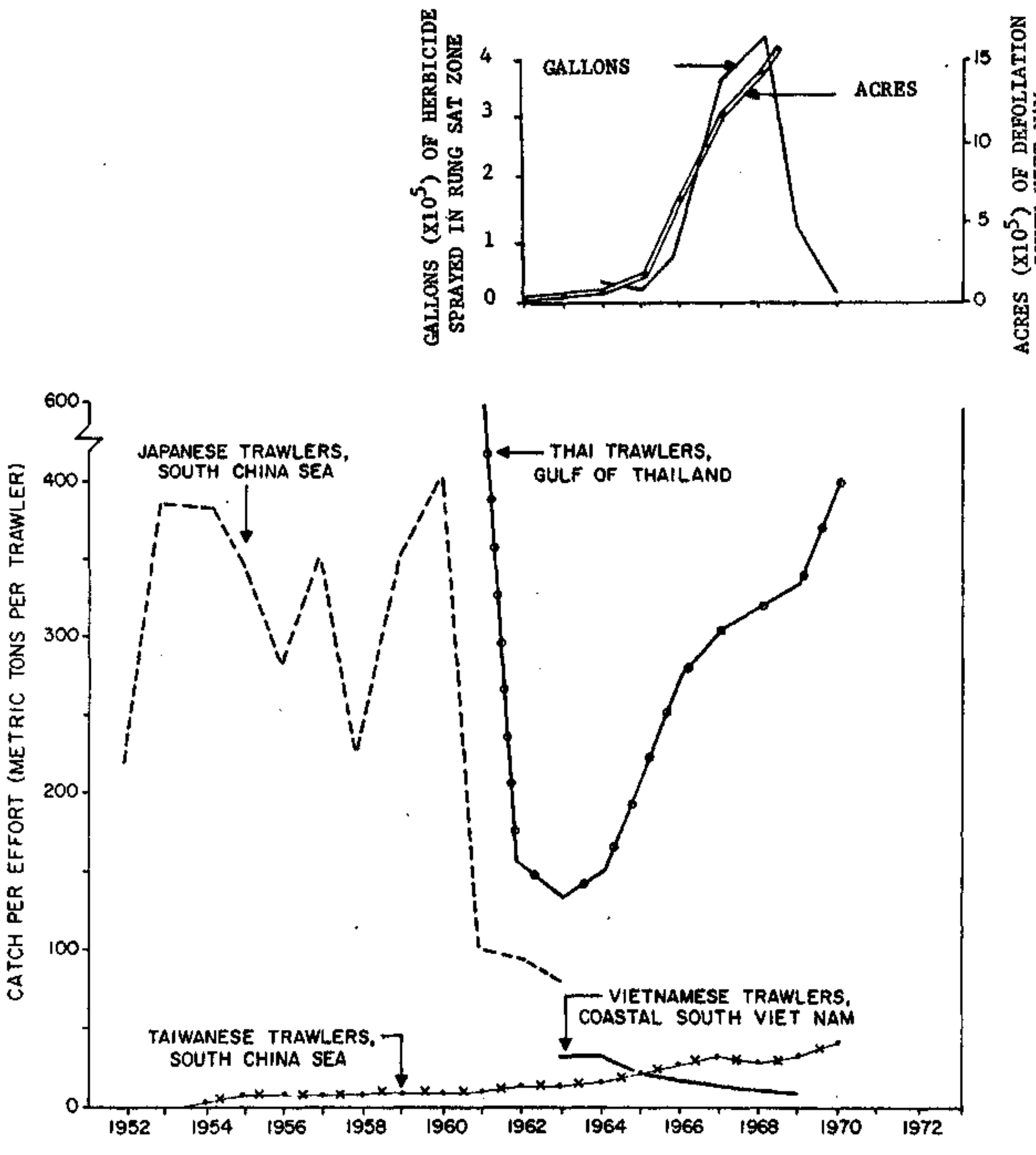

FIG. 11. Catch per unit effort of fishing trawlers in the South China Sea, coastal SVN, and the Gulf of Thailand. Quantity and acreage of SVN sprayed with herbicides in from 1962 to 1970.

the ecological or socioeconomic effects of the war may have contributed to this decrease in effort, in spite of an increase in total fin-fish catch (Table X). In contrast, Thai trawlers working in areas of the Gulf of Thailand and the Taiwanese trawlers fishing the South China Sea, both of which are not affected by wartime activities, show a steady annual increase in the catch and the catch per unit of effort.

Loftas (1970) reported that "the size of fish caught [by Vietnamese fishermen] has decreased until the more popular species have had to be protected by setting size limits."

The decrease in the marine fish catch may also result from general pollution from domestic sewage, war materiel, or extensive spraying of DDT and malathion in Indochina, either alone or in combination with mangrove defoliants. None of these pollutants has been investigated in the aquatic food chain in SVN, but undoubtedly the chain is complexly affected. The somewhat sudden drop in the catch per unit effort after 1964 suggests that it is due not to overfishing by fishermen, but rather to an external factor such as environmental degradation or to some war-related sociological reason.

We lack supporting data to indicate whether or not the decline in the fishery is due to economic or sociological reasons related to the war. Nor is it known if the data presented on the number of motorized vessels used for catching marine fish indicate that these vessels are actually fishing full time, part time, or are even fishing in the same area from one day to the next. Possibly, for example, fuel or adequately trained fishermen are not always available to the motorized fishing fleet. Indeed, certain parts of the coast of SVN are closed completely to fishing for security reasons, while in other sectors fishing is permitted only during certain hours. In some instances, vessels must fish a specified number of kilometers from shore. The added time required to run farther from port would decrease the time actually spent in fishing. Data on these factors are needed to evaluate possible causes and effects of the apparent decline in the fishing catch.

Security regulations on fishing activities plus restrictions following the Tet offensive were not imposed until 1968, whereas the decline in the marine fish catch per unit effort began abruptly in 1964. Extensive spraying of herbicidal defoliants began in 1963, following their limited use in 1961 and 1962 (Tables II and III, Whiteside 1970). One would expect a lag effect between initial widespread use of defoliants and effects on the fishery. It is tempting to compare the decrease in catch per effort by Vietnamese trawlers with the increase in gallons of herbicide or in number of acres sprayed in SVN (Figure 11).

One of the most important fishing ports in SVN is Vunq-Tau (Brouillard 1970). If it can be assumed that in the Vunq-Tau fishing area the fishing catch per unit effort decreased proportionally with the overall decrease in the catch per effort for the total marine fish catch in SVN, it can be stated biologically that most species brought into Vung-Tau and observed by us in the fish markets there are dependent upon estuarine conditions for food, shelter, or as a nursery area. These include anchovies, herrings, flounders, snappers, croakers, porgies, jacks, whitings, mullets, shrimps, crabs, and prawns. Possibly, fishes and invertebrates landed at other South Vietnamese ports, at least south of Cam-Ranh, and east of Rach-Gia, at the Ca-Mau Peninsula, are also dependent upon the Rung-Sat Zone. Hence degradation of the Rung-Sat Special Zone would be expected to result in a decrease in the number of fish that depend upon the estuary for food, shelter, or as a nursery ground.

CONCLUSIONS

On the basis of very short-term studies made in March 1972, October and November 1972, and in January 1973, it may be concluded that defoliation of the mangrove area of the Rung-Sat Special Zone probably did not have a permanently damaging effect on the estuarine ecology of SVN. Biological productivity appears to be sufficiently high, although far from optimum, to permit the survival and feeding of a variety of organisms living in the estuary. It is likely, however, that this zone may have been much more productive prior to defoliation of the mangroves. There is little extensive spawning activity of fishes in the Rung-Sat Special Zone, probably because of the low oxygen saturation of the silt-laden, turbid waters. Nevertheless, larval fishes carried in from downstream are apparently able to survive under these conditions. One concern is that extensive defoliation between 1962-1970 may have resulted in a large "slug" of organic debris from grasses, leaves, twigs, and seeds, which is decomposing rather suddenly, resulting in a large volume of nutrients being added to the environment. Normal decay of plant material and the conversion through detritus to the nutrient cycle should be retarded or prevented because of sudden defoliation (Bormann et al. 1968). This volume of nutrients would be abruptly used by phytoplankton and benthic algae or plants, resulting in "blooms." Yet it could be greater than the zooplankton-benthos mass that uses this large, sudden food supply. Nektonic or benthonic predators might not be numerous enough to use this sudden availability of energy, and thus this food source would not be utilized in the Rung-Sat Special Zone, though it could be assimilated farther downstream toward the Vung-Tau Region. In addition, after this sudden burst of food became available, nutrients would virtually disappear; since energy from mangrove degradation no longer existed, the normal detrital cycle would slow or cease. Hence, it may be anticipated that, unless other sources of nutrients are available in the Rung-Sat estuaries, the fishery will continue to decline.

The Rung-Sat Special Zone probably always was a difficult environment because of the wide tidal range and high tidal current velocities; only the latter might have changed appreciably as defoliation caused increased runoff from land. The increased organic silt load of the Rung-Sat Special Zone that probably followed defoliation is seen as the factor most damaging to the ecosystem of the Rung-Sat. Increased soil erosion following mangrove defoliation has resulted in the river filling with silt. The outcome is that there are fewer habitats for benthic fishes and invertebrates, and a correspondingly smaller area available to the commercial fishery. This siltation has also apparently increased the abundance of tube-building polychaete worms, and has necessitated extensive dredging activities in the Saigon, Nha-Be, and Long-Tau Rivers; these projects add to the turbidity and siltation problem already occurring, destroying more benthic habitats. As long as siltation remains unchecked, turbidity will remain high in the rivers.

Another adverse effect of defoliation is that the resulting high turbidity of the waters in the Rung-Sat Special Zone may interfere with the photochemical degradation of 2,4-D and 2,4,5-T (Agent Orange) which leaches from the mangrove forests and soils of the Rung-Sat Special Zone. As a result, these compounds may persist in water, sediments, or aquatic organisms.

It has been suggested that herbicides might interfere with the production of phytoplankton; the relatively low numbers of diatoms found in the Rung-Sat Special Zone may be due to persistent defoliants, low light penetration, or both.

Because it was not possible to investigate their role and fate in the food web, it cannot be ascertained whether or not herbicides, their contaminants, or breakdown products were detrimental to the organisms in the ecosystem of the Rung-Sat Special Zone, either by killing them directly or by interfering with physiological processes such as spawning, growth, swimming, behavior, and migrations. It is possible that the lower productivity of fish eggs, copepods, diatoms, benthos, and fishes in the Rung-Sat Special Zone in comparison to that of the Vung-Tau Region was a result of residual herbicides in the water, sediment, or organisms. Similarly the role, pathways, and effects of chlorinated hydrocarbons, organophosphates, heavy metals, and other contaminants entering the Rung-Sat Special Zone from upstream is unknown.

Finally, and possibly most important, the probability exists that if any of the above-mentioned contaminants enters the waters of the Rung-Sat Special Zone it will be incorporated into the food web, concentrated as it passes from one trophic level in the food web to each succeeding one, and eventually be passed on, in higher concentrations, because of biological magnification, to persons eating seafoods that have been associated with the food web of the Rung-Sat Special Zone.

RECOMMENDATIONS

1. This study suffered primarily from a lack of comparative background data. It is urged that the GVN and its academic institutions initiate a long-term ecological analysis, including biological, physical, and chemical observations and monitoring of the defoliated areas and aquatic ecosystem in SVN to evaluate recovery rates following defoliation of the mangrove ecosystem. The University of Miami's School of Marine and Atmospheric Science would be in a position to assist in the formulation of such programs, including the training of students and exchange between Vietnamese and American faculty and students.

2. Because fisheries development offers a real economic hope for Vietnam's future (Loftas 1970, Anonymous 1971), in conjunction with ecological studies it is recommended that the GVN institute a carefully-planned system of collecting accurate statistical data which would include, but not be limited to, catches of different species of fish and shellfish at each fishing port, number of boats

fishing on each fishing ground, time spent in actual fishing operations, kind of gear used, and economic data such as number of persons fishing. per boat, costs involved in ship operations, and cost of nets. A logbook system, such as is used in most other countries, would be desirable.

3. A program of replanting the mangroves of the Rung-Sat Special Zone should be initiated by planting seedlings or transplanting small trees. Special attempts should be made to plant the heavily eroded river banks with mangroves or other suitable plants that might reduce bank erosion and the resulting high turbidity of the Rung-Sat waters. Woodcutting activities should be prohibited close to the estuaries in order to maintain a buffer zone of mangroves and thus reduce erosion of river banks.

4. A thorough quantitative analysis of the food web of the Rung-Sat Special Zone is recommended, specifically to identify defoliants such as 2,4-D, 2,4,5-T, picloram, and cacodylic acid and their breakdown products and contaminants (dioxin and pentachlorophenol). Because dioxins also are found in paints, lacquers, and varnishes, sources of these should be searched for upstream of the Rung-Sat Special Zone. Other contaminants such as DDT and related chlorinated hydrocarbons and long-lived organophosphates should be identified, if they exist, in the food web. It would be desirable to identify and trace the pathways of all known contaminants through the water, sediments, organisms, and lower organisms. Finally, they may reach man.

ACKNOWLEDGMENTS

We wish to acknowledge the support of the National Academy of Sciences/National Research Council, Contract No. BA-23-73-47, to the University of Miami. We wish to thank various members of the NAS Committee on the Effects of Herbicides in Vietnam for their advice and assistance in the course of our field work in SVN, specifically Dr. Anton Lang, Committee Chairman, Professor Pham-Hoang-Ho, Professor Le-Van-Thoi, Dr. Fred Tschirley, Dr. Howard T. Odum, Dr. Joseph M. Carrier, and Dr. Philip Ross. We are grateful to Dr. Tran-ngoc-Loi and Mr. and Mrs. Nguyen-Thuong-Dao at the Institut Oceanographique at Nha-Trang, for much advice and assistance, and to Mr. Tran-Van-Tri and Mrs. Nam-Hai of the Department of Fisheries, Saigon. To many Vietnamese Naval personnel who guided and protected us during our field studies we are deeply grateful. Major Gordon Goff and Captain Dean Neptune, Military Assistance Command, Vietnam (MACV), were helpful in many ways.

We wish to thank our colleagues and coworkers at the University of Miami for various support during the field work in Vietnam and subsequent laboratory studies in Miami, including Helen Apuzzo, Maryanna Bogle, W. Connor Davis, Stephen Grund, Roger T. Hanlon, Eric Hildebrand, Raymond F. Hixon, James K. Low, John Markham, Susan McLean, Shirley Pomponi, James F. Quinn, Lewis N. Scotton, Robert C. Trumbull, Robert C. Work, and Bernard Yokel. We are grateful to Dr. Tokiharu Abe, Mrs. Lillian Dempster, Dr. William N. Eschmeyer, Dr. Carl L. Hubbs, and Ms. Terry Loy for assistance in locating pertinent literature.

Mrs. Selma Baron, of the National Academy of Sciences, assisted in many ways through obtaining necessary visas, arranging for shipping of materials, and general advice.

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