Fig. 3 shows the variation of catch in relation to the physical features of sea bottom. From the catch records it appears that the most suitable habitat for this species is sandy bottom with shell pieces.

The variation of catch in relation to the time of operation is shown in Fig. 4. The figure shows that the catches in the night are higher than those in the day time. This is probably associated with its feeding behaviour and may suggest that it buries itself under the substratum in the day, as is the case of some prawn species.

From the encouraging results of the preliminary survey on the distribution and catch of the shovel-nosed lobster further studies need to be carried out before the resource of this economically important crustacean can be fully developed and exploited.

4. Acknowledgement

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Results of the Experimental Trawl Fishing in the South China Sea by R/V CHANGI in the Years 1970 to 1972

by
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Abstract

From the data collected by R/V CHANGI from 1970 to 1972 the trawl fishing grounds in the South China Sea were discussed. To examine the trend of demersal fish resources, the data collected by R/V HAI-CHING in 1960–1962 were also utilized.

The areas near to Tioman Island and off the coast of Sarawak were considered as promising fishing grounds, although the mean catch per hour was not too good. Red snappers predominated the catch in most areas, while

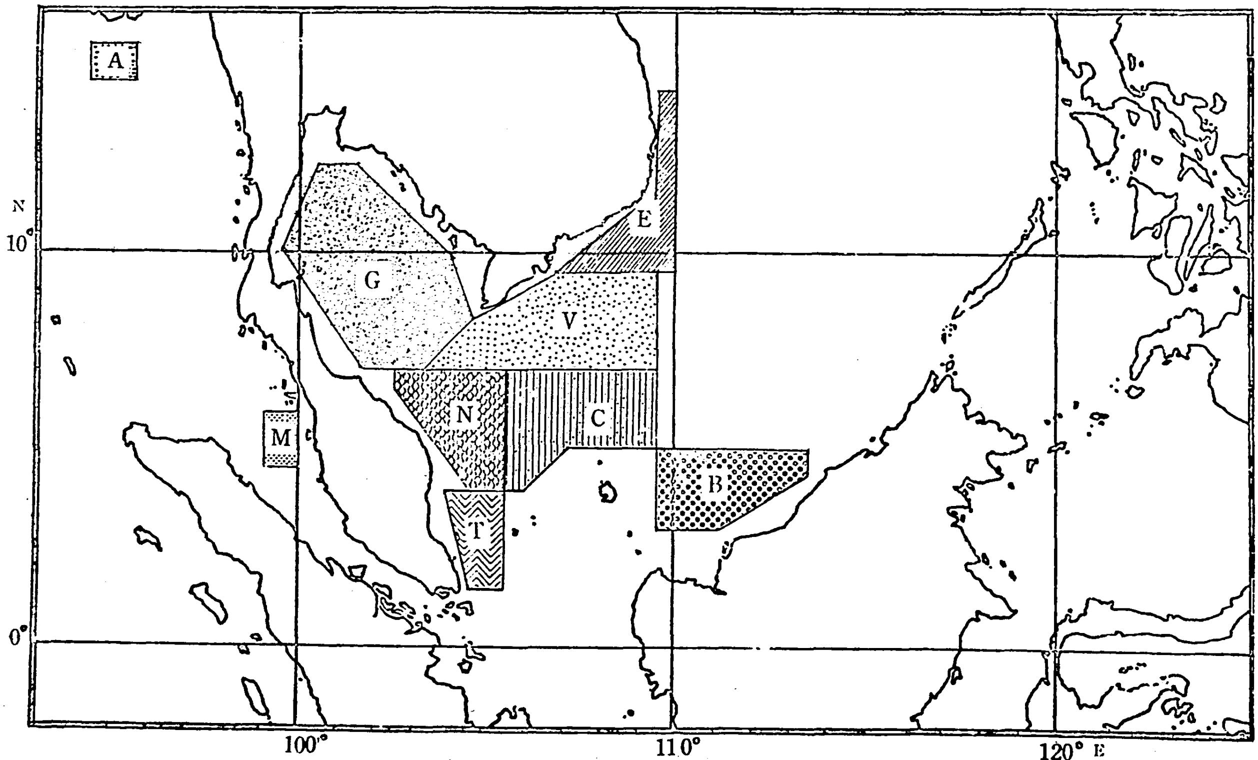

Fig. 1 Map to show the areas of survey.

species composition in the waters off Vietnam was quite different.

Although seasonal fluctuations of both mean catch per hour and species composition were not very much, a remarkable annual fluctuation was observed in species composition.

Good catches were usually obtained from depths of 51–100 m.

Changes in demersal fish resources in the last ten years, both in quantity and quality, if any, may be in a desirable direction.

More study on economic and biological aspects are needed to attain a full exploitation of the fishery resources of the region.

1. Introduction

The research vessel CHANGI of the Marine Fisheries Research Department, Southeast Asian Fisheries Development Center, has been carrying out investigations on demersal fish resources in the Southeast Asian region since early 1970. During the past 3 years, from 1970 to 1972, CHANGI conducted 24 cruises for experimental trawl fishing and made 680 hauls. The present paper summarizes the trawl results of 21 cruises and 623 hauls carried out mainly in the South China Sea.

2. Fishing Gear and fishing grounds

1.2 Vessle and trawl net

R/V CHANGI is a steel boat, 386.6 tons in gross tonnage, equipped with a main engine of 1000 H.P., designed mainly for both stern trawl and tuna long line. The trawl net is four-seamed type, with head rope length of 36 m. and cod-end mesh size of 56 mm. The net was towed at a speed of 2.5 to 4.5 knots for an average of 1.5 hours per haul. The towing speed varied according to the velocity and direction of the current and the bottom

Table I. Number of Trawl hauls and total catch by area and by month by R/V "Changi" in 1970 – 1972

1. 1970

Date \ Area[1]	T	N	B	V	C	G	M	A	Total	Total catch (tons)
8–30, January	13					21			34	4.1
18–20, February	7	6							13	1.4
20–26, April	2		23						25	4.0
14–22, May	1		26		7				34	5.1
15–21, June	24	10							34	5.1
4–26, July		38			6	3			47	8.8
13–19, August		8			23				31	4.3
15–22, October	11	17							28	7.1
17–23, November	17	12							29	6.9
Total	75	91	49		36	24			275	
Total catch (tons)	14.2	18.2	8.3		3.6	2.5				46.8

2. 1971

Date \ Area[1]	T	N	B	V	C	G	M	A	Total	Total catch (tons)
14–26, April	12	14			21				47	6.6
1–12, June	12	14			13				39	9.4
16–27, July							7		7	1.7
1–13, September	10			39					49	7.2
12–24, October	6		37						43	10.4
28 Nov. – 5 December	46								46	11.2
13–20, December							17		17	3.1
Total	86	28	37	39	34		24		248	
Total catch (tons)	19.9	6.1	9.2	4.4	5.2		4.8			49.6

3. 1972

Date \ Area[1]	T	N	B	V	C	G	M	A	Total	Total catch (tons)
19–23, January	18								18	5.6
4–10, February							23		23	3.3
20–24, April	5	5							10	1.3
17, June	4								4	0.5
6–13, October	35								35	8.5
24–30, October	28								28	5.7
15–24, November			29						29	5.4
28 Nov. – 13 December								10	10	6.4
Total	90	5	29				23	10	157	
Total catch (tons)	20.9	0.7	5.4				3.3	6.4		36.7

[1] T: adjacent to Tioman Island, N: northern area off east coast of Malay Peninsula, B: north coast of Borneo, V: south coast of Vietnam, C: central area of south-western region of the South China Sea, G: Gulf of Thailand, M: off Penang Island (Straits of Malacca), A: northern part of Andaman Sea.

topography. During the initial period of operation most towing time ranged from 60 to 120 minutes. However, in 1972 towing time was limited to 1.5 hours whenever possible.

2.2 Areas surveyed and frequency of operation

Figure 1 illustrates the 8 areas (T, N, B,V,C,G,M and A) surveyed by CHANGI in 1970–1972. The data from area M are utilized in this report only for the purpose of comparison but those from area A are fully discussed in a separate paper (Senta and Tan, 1973). Table I illustrates the number of hauls and total catch by area and by month.

Table II. Mean catch per hour (C/h) and coefficient of variation (C.V.) by area and by year

Year	Item \ Area	T	N	B	V	C	G	M
1970	C/h kg	159.9	154.5	149.4	–	80.1	93.2	–
	C.V. %	92.3	65.9	86.9	–	81.4	89.7	–
1971	C/h kg	175.9	126.0	175.7	74.2	91.1	–	130.6
	C.V. %	59.7	53.9	65.7	97.1	62.6	–	63.3
1972	C/h kg	176.8	120.0	154.5	–	–	–	170.5
	C.V. %	82.3	42.2	70.0	–	–	–	76.7

3. CATCH AND SPECIES COMPOSITION

3.1 Catch per hour and its fluctuation by area

The mean catch per hour for each area during the 3 years is shown in Table II. While areas T and B gave the best mean catch values of more than 150 kg/hour, areas V, C and G gave a value of less than 100 kg/hour. The remaining two areas, N and M, may be considered to give intermediate values of mean catch per hour, although the values varied from year to year.

The value of coefficient of variation (C.V.), which shows the degree of fluctuation of catch either spatially or temporally, was always lowest in area N. The values of C.V. were nearly the same in areas T, B, C, G and M, although the values in any of these areas fluctuated considerably from year to year. The value was considerably higher in area V, thus suggesting that the catch per hour fluctuated markedly in this area.

Based on trawl catches these areas can be categorized into 3 types of fishing grounds. Areas T and B are considered as good fishing grounds with high catches; areas N and M are intermediate while areas V, C and G are regarded as poor fishing grounds.

Table III. Percentage in weight of major species in total trawl catch by area of 1970

Species* \ Area	T	N	B	C	G
1 Red snapper	25.2	13.6	25.3	15.5	26.6
2 Bigeye snapper	8.1	17.1	18.9	10.9	1.6
3 Threadfin snapper	3.9	6.4	2.8	3.9	2.9
4 Triggerfish	5.7	9.7	4.5	3.2	1.9
5 Jacks and scad	4.7	5.7	3.3	15.0	4.4
6 Naked-headed sea bream	2.6	3.2	3.9	2.7	0.2
7 Thick-lip grunt	5.4	2.8	7.3	0.0	2.4
8 White snapper	3.7	4.6	2.4	1.0	4.8
9 Lizardfish	2.7	5.8	2.3	10.5	3.1
10 Goatfish	4.0	8.7	4.2	6.5	4.5
11 Catfish	1.3	2.9	3.0	1.3	0.7
12 Grouper	1.9	1.7	3.0	0.9	0.7
13 Rabbitfish	0.5	0.9	0.0	3.1	0.2
14 Soldierfish	0.0	0.5	0.1	0.4	0.0
15 Barracuda	0.1	0.6	0.5	0.1	1.4
16 Sea bream	0.0	0.0	0.0	0.0	0.0
17 Butterfish	0.0	0.5	1.4	0.0	0.0
18 Croaker	0.0	0.1	0.1	0.2	0.0
19 Shark	3.1	2.8	2.0	7.2	0.5
20 Others	14.3	10.1	7.5	12.8	11.6

*1: large sized lutjanid, 2: Priacanthus, 3: nemipterid, 4: Abalistes, 5: carangoid, 6: Gymnocranius, 7: Plectorhynchus, 8: Pristipomoides, 9: Saurida and Trachynocephalus, 10: mullid, 11: Tachysurus, 12: epinephelid, 13: Siganus, 14: Holocentrus, 15: Sphyraena, 16: Taius and Argyrops, 17: Ariomma, 18: Sciaenid, 19: small sized sharks

Table IV. Percentage in weight of major species in total trawl catch by area in 1971

Species \ Area	T	N	B	V	C	M
1 Red snapper	22.2	24.9	22.4	19.2	10.3	7.7
2 Bigeye snapper	18.3	10.6	15.2	1.1	18.2	11.8
3 Threadfin snapper	11.2	2.4	8.7	3.9	10.5	9.6
4 Triggerfish	7.2	8.1	4.6	0.9	9.9	5.3
5 Jacks and scad	5.9	8.4	3.1	11.7	6.3	8.4
6 Naked-headed sea bream	5.6	3.9	4.8	3.5	5.1	2.1
7 Thick-lip grunt	4.1	3.2	6.3	6.1	0.6	1.6
8 White snapper	3.7	3.7	2.9	4.1	2.5	3.7
9 Lizardfish	3.6	3.1	3.9	14.6	5.9	2.3
10 Goatfish	3.0	6.3	9.1	4.4	6.9	12.3
11 Catfish	1.8	1.6	1.6	0.0	3.7	8.3
12 Grouper	1.7	1.8	2.0	2.6	2.2	2.1
13 Rabbitfish	0.5	0.3	0.1	0.2	0.4	10.1
14 Soldierfish	0.1	0.3	2.9	0.1	0.1	0.7
15 Barracuda	0.1	6.2	0.2	0.0	0.0	0.0
16 Sea bream	0.0	0.0	0.3	1.7	0.0	0.1
17 Butterfish	0.0	0.0	3.7	17.3	0.3	0.1
18 Croaker	0.0	0.1	2.4	0.0	0.5	0.0
19 Shark	2.9	3.5	1.8	2.2	8.5	1.3
20 Others	8.1	11.6	4.0	6.4	8.1	12.5

3.2 Species composition in catch by area

Tables III, IV and V illustrate the percentages in weight of total catch for each of the major species in the respective areas and years. It can be seen that red snappers were always the most abundant fish in T, B, V and G, usually consisting of more than 20% of the total catch. In areas N and C, red snappers were still dominant, but with rather lower percentages (10–15%) except for area N in 1971 (25%). Among the red snappers *Lutjanus sanguineus* was the most important species, usually occupying about 70% of the total catch of snappers. Other important red snappers were *L. sebae* and *L. altifrontalis* (= *L. malabaricus phuketi*). Bigeye snappers, comprising mainly *Priacanthus tayenus* and *P. macracanthus,* were the next most abundant fish except in areas V, G and B where the fish occupied less than 2% of the total catch.

Percentages in weight of trawl catch for all other species varied considerably from area to area. Extreme examples of such a case are: In 1970 triggerfish occupied 9.7% in area N, but only 1.9% in area G; jacks and scad constituted 15.0% in area C, followed by 5.7% in area N; the percentages of lizardfish ranged from 10.5% in area C to 2.3% in area B. In 1971 lizardfish occupied 14.6% in area V, followed by 5.9% in area C; rabbitfish was caught in a significant amount only in area M; butterfish occupied 17.3% in area V, followed by 3.7% in area B and with negligible catches in other areas; barracuda were captured in much higher percentage in area N than in any other area. In 1972 the percentages of triggerfish ranged from 18.2% in area M to 0.6% in area B; catfish occupied 15.3% in area M, followed by 8.2% in area B; croaker, shad, golden snapper, grunter and conger eel occuurred in significant amount only in area B.

Table V. Percentage in weight of major species in total trawl catch by area in 1972.

Species* \ Area	T	N	B	M
1 Red snapper	23.0	10.4	12.9	6.0
2 Big-eye snapper	16.0	38.2	0.8	13.4
3 Threadfin snapper	7.4	8.5	1.4	3.7
4 Triggerfish	8.4	9.0	0.6	18.2
5 Jacks & Scad	7.5	6.7	12.0	4.9
6 Naked-head sab.	4.5	3.1	0.2	4.2
7 Thick-lip grunt	4.1	1.6	2.6	5.4
8 White snapper	4.6	3.3	0.1	0.7
9 Lizardfish	4.0	2.7	3.1	0.0
10 Goatfish	4.7	6.0	0.0	5.7
11 Catfish	5.7	3.1	8.2	15.3
12 Grouper	5.5	0.8	1.3	3.0
13 Rabbitfish	0.0	0.2	0.0	3.3
14 Soldierfish	0.0	0.0	0.0	0.0
15 Barracuda	0.7	0.0	0.0	0.0
16 Seabream	0.0	0.0	0.0	0.0
17 Butterfish	0.0	0.0	0.0	0.0
18 Croaker	0.0	0.0	12.0	0.0
19 Spanish mackerel	0.2	0.0	1.1	1.1
20 Shad	0.0	0.0	10.9	0.0
21 Golden snapper	0.0	0.0	7.5	0.0
22 Grunter	0.0	0.0	3.5	0.0
23 Conger eel	0.0	0.0	1.5	0.0
24 Sharks	0.0	4.9	6.0	1.3
25 Others	3.0	0.6	12.8	13.5

* 19: Scomberomorus, 20: Ilisha & Pellona, 21: Lutjanus johnii, 22: Pomadasys, 23: Muraenesox talabon

Sea bream caught in area V was almost exclusively *Taius tumifrons*, and those in other areas were *Argyrops spinifer*. Among those species which are included in "others" in Tables III-V, hairtail (*Trichiurus*), cobia (*Rachycentron*) pigfacefish (*Lethrinus lentjan* and *L. miniatus*), cuttlefish and squid, shovel-nosed lobster, etc. were of some importance sporadically.

In order ot compare further the species composition in catch between areas, the community similarity index, Cλ (Morisita, 1959) was calculated for the data of 1970 and 1971. Before calculating the index, the catch record in weight of each species in each area was converted into an individual number by dividing the catch by an average body weight of the species. The latter was taken from the record of measurement on the catch made mainly in 1971. "Others" were omitted from the calculation.

The values of Cλ for every possible comparison of two areas in the respective years are shown in Table VI. The index becomes one when the communities of the two areas are the same and becomes zero when no common species is found between them. Furthermore, the index is almost independent of sample size provided that samples of either or both areas are not small.

In 1970, high values of Cλ were observed for every combination of two areas, most of them exceeding 0.9. The values are especially high between areas T and N, areas T and G, and areas C and G. Even between areas B and C where the lowest similarity was seen, the value of Cλ was still rather high.

At the left-bottom half of Table VI a remarkable difference of community between area V and the other areas is obvious, 4 out of 5 values of Cλ being 0.23–0.28. The higher value of Cλ between areas V and B (0.51) indicates the existence of more similarity of the community between them than those of the otehr areas.

The highest similarity of community in 1971 is seen between areas T and C, and followed by that between areas B and C, both with values of Cλ exceeding 0.9. Notwithstanding the proximity of area N to area T, the value of Cλ between these two areas was rather low as compared to those of the other values, except those of area V. On the other hand, the community of area M showed a rather high similarity with the other areas (Cλ being 0.76–0.86) excepting area V, in spite of the fact that area M is connected with the other areas only through the narrow Straits of Malacca.

Table VI. Community similarity index (Cλ) between areas calculated for 19 major species in trawl catch in 1970 (right-top) and in 1971 (left-bottom)

	T	N	B	V	C	G	M
T		0.990	0.943	–	0.958	0.983	–
N	0.715		0.956	–	0.915	0.960	–
B	0.828	0.777		–	0.846	0.878	–
V	0.229	0.268	0.511		–	–	–
C	0.963	0.829	0.910	0.280		0.985	–
G	–	–	–	–	–	–	–
M	0.759	0.794	0,833	0.265	0.856	–	–

3.3 Seasonal fluctuation in catch and species composition

As shown earlier in Table I area T has been visited most frequently by CHANGI. Catch data in area T, therefore, was utilized for the purpose of analysing seasonal fluctuation in catch and species composition. Because of the scarcity or lack of data for some months, a year was arbitrarily divided into 4 peridos: January-March, April–June, July–September and October–December.

The VII shows the number of hauls, catch and species composition for the respective periods in area T. Of the 251 hauls made in area T 143 hauls(57% of total) were operated in October–December, while only 10 hauls were made in July–September.

The catch was the best in the July–September period, with the highest value of mean catch per hour and the least value of C.V. This small fluctuation however, may be a superficial one, because all the hauls were made in the same cruise in September, 1971, thus being free from the influence of monthly or annual fluctuations. The values of mean catch per hour were almost the same in both periods of January–March and October–December, but the catches were more stable in the latter period. The April–June period gave a rather poor catch with a comparatively high fluctuation. However, even in the poorest quarter of January–April the mean of catch per hour in area T was actually not as bad as those of other areas in the South China Sea shown in Table II.

In all four quarters, red snappers occupied the highest weight percentage occupying 21–28% of total catch. Although the percentage of red snappers was lower in October-December than in the other periods the seasonal fluctuation in the relative abundance of the fish was not very much. Bigeye snapper comes next to red snapper except in January–March when catfish outweighed bigeye snapper. Threadfin snapper occupied the third position in July–September and October–December but with much lower ranking in the other periods, while triggerfish always maintained at the fourth or fifth position in weight percentage of catch.

In order to express the degree of seasonal fluctuation in relative abundance of a fish, the seasonal fluctuation index, SFI, as defined below was calculated.

Thus, the fishes in Table VIII can be divided into 4 groups according to the degree of seasonal fluctuation in their relative abundance. The following shows the grouping of the fishes.

(a) Low seasonal fluctuation(SFI<2) : red snappers, triggerfish, naked-headed sea bream, white snapper, lizerdfish and soldierfish.

(b) Moderate seasonal fluctuation (SFI = 2.1 to 5.0): bigeye snapper, jacks and scad, thick-lip grunt, goatfish, grouper, rabbitfish, Spanish mackerel and shark.

(c) High seasonal fluctuation (SFI = 5.1 to 10.0): threadfin snapper.

(d) Extreme seasonal fluctuation (SFI < 10.1): catfish and barracuda.

The pattern of seasonal fluctuation in relative abun-

Table VII. Mean catch per hour, coefficient of variation and percentage in weight of major species in total catch by season in area T for 1970 – 1972

	Jan.–Mar.	Apr.–Jun.	July–Sept.	Oct.–Dec.	SFI*
Total number of hauls	38	60	10	143	
Total catch (kg)	8902	10947	2755	32056	
Mean catch per hour (kg)	175.6	148.8	184.4	176.4	
Coefficient of variation (%)	103.5	99.6	41.0	64.1	
Major species	%	%	%	%	
Red snapper	27.8	26.1	28.1	21.1	1.3
Bigeye snapper	9.0	8.3	14.2	18.5	2.2
Threadfin snapper	2.0	5.3	9.9	10.5	5.1
Triggerfish	7.1	6.1	6.1	5.5	1.3
Jacks and scad	2.4	5.0	8.4	7.8	3.4
Naked-headed sea bream	4.0	3.0	5.1	5.0	1.6
Thick-lip grunt	6.4	8.7	5.7	3.9	2.2
White snapper	3.6	4.7	3.3	4.6	1.4
Lizardfish	3.2	2.9	6.0	4.0	2.0
Goatfish	5.8	7.3	3.0	4.0	2.4
Catfish	11.5	2.5	0.7	1.3	14.5
Grouper	3.8	1.7	2.2	1.7	2.2
Rabbitfish	0.1	0.2	0.7	0.4	4.0
Soldierfish	0.0	0.1	0.0	0.1	2.0
Barracuda	1.7	0.2	0.3	0.0	18.0
Seabream	0.0	0.0	0.0	0.0	–
Spanish mackerel	0.1	0.1	0.5	0.9	4.5
Croaker	0.0	0.0	0.0	0.0	–
Sharks	3.5	3.0	1.4	3.8	2.6
Others	8.0	14.8	7.6	6.9	–

*SFI: Seasonal fluctuation index

dance of those fishes belonging to groups (b) and (c) is different according to the species. The percentages of bigeye snapper, threadfin snapper and Spanish mackerel were highest in October–December, followed by those in July–September. On the contrary, catfish and barracuda showed much higher percentage in January–March than in any other periods.

Table VIII shows the community similarity index between periods in area T. This table indicates a high similarity between January–March and April–June and also between July–Stptember and October–December.

3.4 Annual fluctuation in catch and species composition

With reference to Table II the values of mean catch per hour in each area did not show a very high annual fluctuation, the difference between the highest value of mean catch per hour and the lowest value being less than 30% in any area. Among all the areas area T showed the least annual fluctuation, where the lowest value of 159.9 kg/hr in 1970 is only 10% less than the highest catch of 176.8 kg/hr in 1972.

The annual fluctuations of the species composition of trawl catch in areas T and B are discussed, based on the data obtained in the years 1970, 1971 and 1972. The other areas were excluded from this discussion because of insifficiency of data (Tables I, III, IV and V).

In all the three years surveyed red snapper predominated the catch in area T, occupying about 22–25% of the total catch. In 1971, 1972, bigeye snapper and threadfin snapper constituted a greater proportion of the catch than in 1970. The percentage of triggerfish was also higher in 1971 and 1972 but only slightly in 1970. The catch of other fishes like white snapper, lizardfish, grouper, thick-lip grunt and goatfish did not show any large fluctuations. Although red snapper and bigeye snapper always occupied the top and second positions in abundance in the trawl catch, the ranking of the other fishes changed annually.

Table VIII. Community similarity index (Cλ) between periods calculated for 19 major species in trawl catch in area T. The data for 1970 – 1972 are combined.

	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.
Jan.–Mar.	–	0.934	0.743	0.770
Apr.–June	0.934	–	0.856	0.868
July–Sept.	0.743	0.856	–	0.988
Oct.–Dec.	0.770	0.868	0.988	–

Table IX. Community similarity index (Cλ) between years calculated for 24 major species in area T (right-top) and B (left bottom)

	1970	1971	1972
1971		0.430	0.520
1971	0.475		0.958
1972	0.437	0.170	

The trawl catches in area B in 1970 and 1971 were not much different from the catch in area T, with red snapper predominating in the catch. Bigeye snapper and threadfin snapper were also quite abundant. However in 1972, the species composition differed considerably from that of the previous two years. Here red snapper, jacks and scad, croaker and shad were equally abundant. Bigeye snapper occupied only a small percentage of the catch. Threadfin and goatfish were also caught in negligible amounts. A considerable amount of golden snapper, conger eel, shad and grunter were caught in 1972, even though they were almost negligible or totally absent in 1970 and 1971.

The community similarity index, Cλ, was calculated and shown in Table IX for further examination of differences in species composition between years. The table indicates that between 1971 and 1972 the species composition in area T was quite similar but between 1970 and 1971 and between 1970 and 1972, the Cλ were rather low, much lower than those between periods (Table VIII).

In area B, Cλ showed an extremely low value between 1971 and 1972. The similarity was slightly greater between 1970 and 1971 and between 1970 and 1972.

The relatively low values of Cλ in general, which suggests the existence of annual fluctuation in species composition, may be attributed to the annual fluctuations of rankings of main species other than red snapper bigeye snapper. The extensively low Cλ in area B between 1971 and 1972 may be related to the locality of the fishing ground. In 1972, most of the trawl operations were carried out in shallow waters (26–48 m), close to the coast. Hence the water conditions here differed considerably from the areas trawled in 1970 and 1971 which were towards the open sea.

Table X. Number of hauls by depths of fishing ground in each area, 1971

Depth(m)	26–50	51–75	76–100	101–125	126–150	Total
Area T	8	78				86
N	5	23				28
B	6	15	11	5		37
V	10	9	8	8	4	39
C		15	15		4	34
M	4	19	1			24

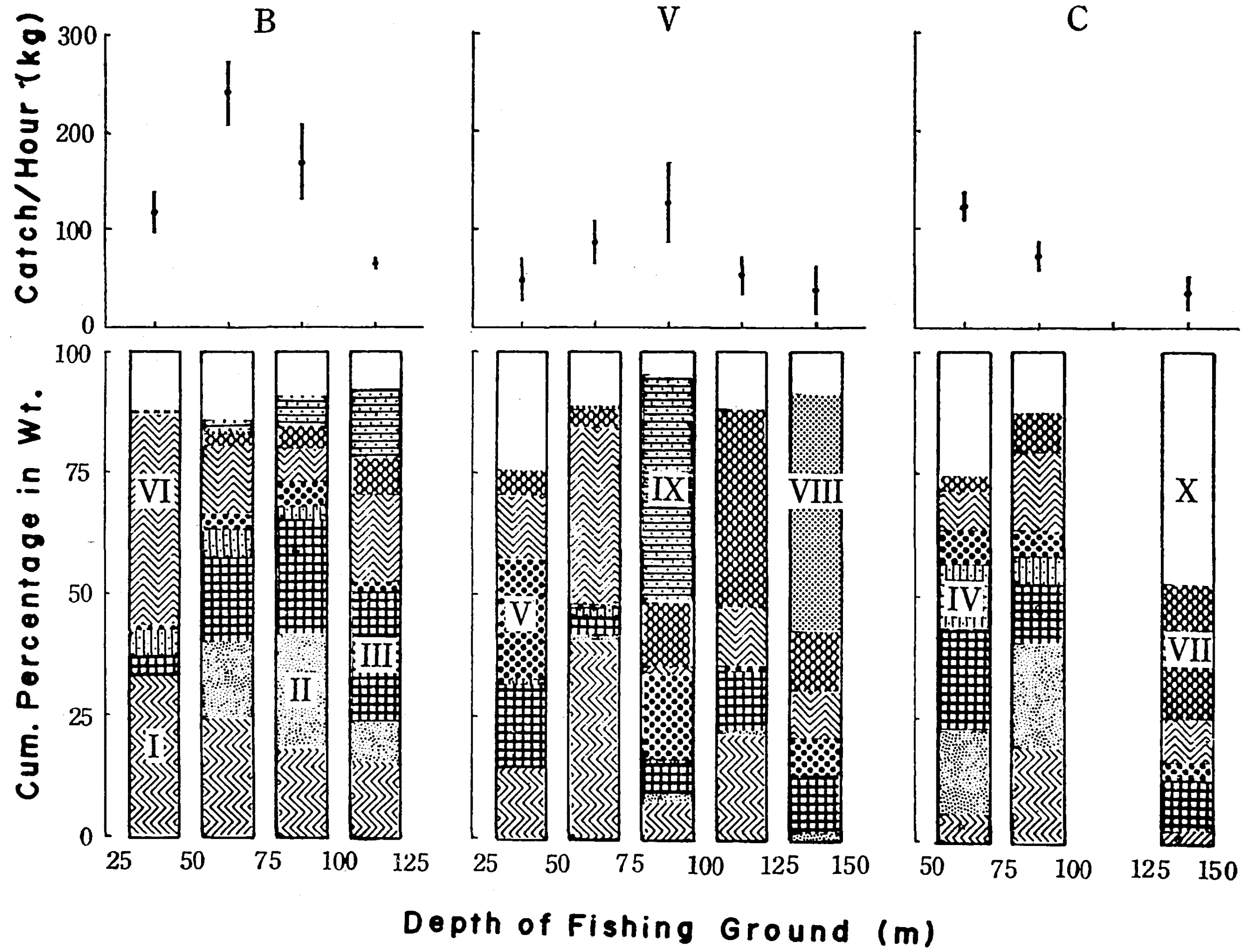

Fig. 2 Variation in trawl catches in the South China Sea by depths.

Top: mean catch per hour and its 70% confidence limits.

Buttom: species composition of catch. I, red snappers; II, bigeye snapper; III, threadfin snapper and goatfish; IV, triggerfish; V, jacks and scad; VI, naked-headed sea bream, thick-lip grunt, white snapper and grouper; VII, lizardfish; VIII, sea bream; IX, butterfish; X, others.

B, V and C on the top show areas.

3.5 Catch and species composition by depth

Table X illustrates the number of hauls at different depths of 25 m. intervals in all six areas in 1971. It can be seen that the fishing grounds in areas B, V and C covered a wide range of depth while those in areas B, V and C covered a wide range of depth while those in areas T, N and M were limited to waters shallower than 75 m. For this reason the study on the relationship between depth and fish catch is based on data collected from areas B, V and C.

The mean catch per hour and their 70% confidence limits by depths and by areas are shown in the upper portion of Fig. 2.

In area B, the best mean catch was obtained at the depth between 51 and 75 m, and the next was at 76–100 m, with no overlap in their confidence limits. At the depth of 101–125 m, the mean was very low and with a very narrow range of confidence limits indicating that every haul made at this depth yielded very poor catch.

In area V, the best catch occurred at depth of 76–100 m, followed by 51–75 m, with overlapping confidence limits. The poorest was at 126–15o m, although its confidence limits overlap those of 26–50 m. and 101–125 m.

In area C, the mean catch was the best at 51–75 m, followed by 76–100 m and 126–150 m, with no overlap in their confidence limits.

The lower half of Fig. 2 shows the species composition of catch. The 20 categories of fish groups as illustrated in Table V are regrouped into 10, by combining 2 or more fish groups whose habitats, sizes, market values, etc. are roughly the same, and by lumping together fish which did not occur in significant abundance in areas B, V and C into the category "others" (designated as X in Fig. 2).

The depth at which red snappers (I) showed the highest percentage differed by areas, although the absolute abundance of the fish, which is a product of the catch per hour and the percentage of the fish at each depth, was the highest at 51–75 m in areas B and V and at 76–100 m in area C. Almost no red snapper was caught in waters deeper than 126 m.

Naked-headed sea bream, thick-lip grunt, white snapper and grouper are collectively designated as VI in Fig. 2. The variation in the percentage of the group by depths was almost parallel with that of red snappers.

Bigeye snapper (II) did not occur at the shallowest depth and very few were captured in depths exceeding 125 m. The fish was abundant in the waters between 51 and 100 m. deep, although in area V the catch was neglible at any depth.

Threadfin snapper goatfish (III) and jacks and scad (V) occurred over the whole range of depth, and it is rather difficult to point out a general tendency of the variation in the percentage by depths.

triggerfish (IV) was most abundant at depth between 51 and 75 m. and were not found at depth exceeding 100 m.

Lizardfish (VII) occurred over the whole range of the depth with a clear tendency of being distributed most abundantly at depth between 101 and 125 m.

Butterfish (IX) was caught over a depth range between 51 and 125 m. in area B and between 76–100 m. in area V. It is likely that the center of distribution of this fish is at the depth between 76 and 100 m.

Sea bream (VIII) consisted of two species which showed quite different distributions. *Taius tumifrons* was obtained only at depth between 126 and 150 m. in area V, occupying nearly 50% of total catch. On the other hand, *Argyrops spinifer*, though not abundant, occurred exclusively at depth between 51 and 75 m.

4. CHANGE IN TRAWL CATCH AT AN INTERVAL OF TEN YEARS

Ten years preceding CHANGI's trawl survey, intensive experimental trawl operations in the South China Sea were carried out by the research vessel HAI-CHING of Taiwan Fisheries Research Institute. In order to clarify if any significant change occurred in the trawl catch during this ten year period, the results of experimental trawling by HAI-CHING in 1960–1962 were compared with those by CHANGI in 1970–1972 as follows.

4.1 Data used

Tseng (1962) reported the results of investigations of HAI-CHING for 1954 and 1960–1962, of which the 1960–1962 data were utilized here. As the names of fishes in the report was written in Chinese[1)] and with no mention of trawling time per haul Wei's report (1961) on the 1960 operations was also referred to.

HAI-CHING is a boat of 157.9 tons with an engine of 380 H.P. The trawl net is of 500 meshes (mesh size is not shown), each 250 meshes on upper and lower seams, and was towed for 3 hours at a speed of 3 knots at each station. The surveyed area is divided into square blocks of 30 miles on each side, and each block is numbered. In Tseng's report, the following items are given by block and by trip: number of hauls, both the best catch per haul and average catch per haul in terms of fish-boxes (a box containing 25 kg. of fish), percentage of each major fish species.

The percentage of each fish species was back-calculated into weight, by consecutive multiplication of number of hauls by average catch (box) by 25 kg. by percentage. The blocks were regrouped into 7 areas, T, N, B, V, C, G, and E, as shown in Fig. 1. Thus catch per hour and percentage of each species in total catch were newly calculated for each area. These were compared with the results obtained by CHANGI the fishing gear of which was already given in 2.1.

Although more than 30 species as a whole are recorded in Tseng's report, usually only several species are named to show the species composition in each block. Instead, such categories as "mixture of high grade fishes", "mixture of medium grade fishes" and "mixture of low grade fishes" occur frequently and with quite high

1) An English translation by Yamamoto (1967) includes some mistranslation of fish names. The most serious among them is taking a red snapper, *Lutjanus erythropterus* (=L. *sanguineus*) as a soldierfish, *Myripristis murdjan.*

Table XI. Number of trawl hauls and catches by areas in 1960–62 by HAI-CHING and in 1970–72 by CHANGI

Item \ Area	T	N	B	V	C	G	E
1960–62							
No. of hauls*	68	3	40	20	25	222	191
Total catch (ton)	2.4	0.12	7.1	2.3	3.7	65.9	59.1
Catch/hour (kg)	118.4	14.0	58.9	38.8	48.8	98.9	87.0
1970–72							
No. of hauls**	241	124	115	39	70	24	0
Total catch (ton)	54.9	25.0	22.9	4.4	8.8	2.5	–
Catch/hour (kg)	151.9	134.4	132.8	75.2	83.8	69.4	–

* trawling time per haul: 3 hours
** trawling time per haul: 1.5 hours on average

Table XII. Comparison of species composition of trawl catches during 1970–72 by areas with those of ten years ago.

Species	Area	T		B		V		C		G	
	Year	60–62	70–72	60–62	70–72	60–62	70–72	60–62	70–72	60–62	70–72
		%	%	%	%	%	%	%	%	%	%
Red snapper		6.7	23.0	9.9	22.9	42.8	19.2	4.2	12.4	15.0	26.0
Big-eye snapper		1.2	14.7	14.2	13.0	0	1.1	19.1	11.5	2.7	1.6
Threadfin snapper		2.8	7.8	12.8	6.0	0	3.9	24.6	7.8	4.4	2.9
Goatfish		17.4	3.9	6.4	5.6	0	4.4	2.1	6.8	15.0	4.5
Jacks and scads		1.8	6.0	9.2	4.8	5.4	11.7	23.3	10.0	7.8	4.4
Thick-lip grunt		2.1	4.4	1.3	6.0	12.9	6.1	0	0.4	0.5	2.4
Lizardfish		1.8	3.9	3.5	2.4	5.4	14.6	0.7	7.8	6.5	3.1
Catfish		7.3	3.2	1.4	3.4	0	0	3.4	2.7	4.2	0.7
Grouper		0.3	2.0	0	2.7	0	2.6	0	1.7	1.0	0.7
Shark		0.2	1.9	3.2	2.5	1.1	2.2	1.4	7.9	1.1	0.5
Others		58.4	29.2	38.1	30.7	32.4	34.2	21.2	31.0	41.8	52.6

percentages, suggesting that those which may or may not otherwise be named are put in one of these categories when a catch of the fish in an individual haul was less than 25 kg. For this reason, only 10 species were comparable between the data by HAI-CHING and those by CHANGI.

4.2 Comparison of catch per hour

Table XI shows the number of hauls, total catch and catch per hour by area in 1960–62 and in 1970–72. As only 3 hauls were made in area N in 1960–62 and no hauls in area E in 1970–72, these 2 areas are excluded hereafter.

Except area G, catch per hour was always higher in 1970–72. The difference in catch per hour was biggest in area B (2.3 times) and smallest in area T (1.3 times). Only in area G, catch per hour was 1.4 times more in 1960–62 than in 1970–72.

Table XIII. Coefficient of correlation in ranking of ten species between 1960–62 and 1970–72 by areas

Area	T	B	V	C	G
Coef. Correl.	0.321	–0.068	0.782	0.697	0.855

4.3 Comparison of species composition

Percentages occupied by each of 10 species in total catch in 1960–62 and in 1970–72 are shown in Table XII.

A remarkable difference in species composition between 1960–62 and 1970–72 was seen for all areas except area G. Red snapper occupied a much lower percentage of the total in 1960–62 than in 1970–72 except only area V. In 1960–62 this species comprised less than 10% of total in areas T, B and C, although the percentage of the fish was very high in area V and rather high in area G. On the other hand in 1970–72, red snapper usually occupied nearly or more than 20% in all areas except area C where the fish even comprised 12.$%. Percentage of bigeye snapper by area was in a very good accordance between both periods for most areas, although the fish showed a much lower percentage in area T in the former years than in the latter. The other fishes also showed more or less differences in percentage between both periods as seen in Table XII. Among them, grouper which comprised 1.7–2.7% of total in areas B, V and C in 1970–72 is not recorded in these areas in 1960–62.

Table XIII shows the coefficient of correlation in ranking of the ten species between 1960–62 and 1970–72 for each area, for the purpose of examining the similarity of the species composition between both periods.

Although the coefficients of correlation in ranking were high in areas V, C and G, those in areas T and B werre very low, suggesting almost no similarity between 1960–62 and 1970–72 in the latter two areas.

5. DISCUSSION

5.1 Evaluation of the surveyed areas as trawl fishing ground

From the results given in3.1, areas T and B may be reagarded as promising fishing grounds, although the average catch per hour (150–177 kg/hr) cannot be considered as high, as compared, for instance, with the catch per hour (259–690 kg/hr) in the fishing grounds in north Andaman Sea (Senta and Tan, 1973). However, in the present study, the trawl operations were not concentrated on any one special section of each area, because the main aim of experimental trawl operation by CHANGI has been to cover as wide an area as possible in order to get an overall knowledge of distribution of trawl fishery resources. Therefore, it is believed that the mean catch can be increased further if commercial trawl operations are focussed only on certain sections of each area where good catch was obtained.

The maximum catch per hour may be roughly assessed from the following facts. The best catch of a single haul ever experienced by CHANGI was 1081 kg. (1070 kg/hr) at 02°30'N, 104°50'E on January 20, 1972. Catfish predominated the catch (87% of total). The second best catch was 889 kg. (523 kg/hr) at 04°07'N, 111°49'E on October 20, 1971. Red snappers occupied 54% of the catch, and white snappers 9%. On that day 5 operations were made in an area of 10 miles by 20 miles around the above mentioned point, giving the mean catch of 312.5 kg/hr with C.V. of 56%. The third best catch was obtained at 03°02'N, 104°42.5'E on December 1, 1971, with the catch of 504 kg/hr. Red snapper made up 19% of the catch, and several other fishes of good market value collectively occupied 38%.

Even in area V where the catch per hour was extremely low, it is not impossible to exploit payable fishing grounds. That the value of coefficient of variation in area V was very high suggests that the distribution of fishes in this area was very contagious, showing high densities of fishes in some special parts.

The central or deeper parts of the south-western South China Sea (area C) seems to be less promising, because not only was the catch per hour low but also the value of coefficient variation was rather moderate. Therefore, good fishing grounds in this area, if any, must be limited.

With regards to average catch per hour by depth in the South China Sea, it is still too early to draw any conclusion as the available data is far from sufficient. However, it can be said that good fishing grounds are generally found in waters of depths 51–100 m. The catch at this depth is not only reasonable, but also of good market value. Highly valued fish such as red snappers, white snapper, grouper, naked-headed sea bream, make up a considerable part of the catch.

The distribution of fishes, or the formation of fishing grounds, may not be affected only by depth itself. Topography and quality of the sea bottom, distribution of the water masses and currents along the sea bottom, together with the biological environment (existence of corals, large sized sponges, etc., abundancy of food organisms) are important factors in the formation of fishing grounds.

Studies on ecology as well as behaviour, habitat and feeding habit of fishes on the tropical Pacific Ocean have been published by Hiatt and Strasburg (1960), Randall and Brook (1960) and Helfrich et al. (1968). However, such studies were carried out on the coral reefs in the central Pacific Ocean and consequently in shallow waters. Except for a report concerned with commercial fishes in the Tonkin Bay by Vien (1968), which referred briefly to individual species, there is almost no report on ecological aspects of commercial bottom fishes in the South China Sea.

In order to understand the mechanisms of fishing ground formation, the urgent need for the ecological studies of demersal fishes in the South China Sea cannot be over-emphasized. Similarly, as mentioned in 3.3, since there is a considerable seasonal fluctuation in catch per hour and species composition in areas where the annual fluctuation of oceanographic factors is rather limited in comparison with sub-tropical or temperate seas, a more detailed knowledge of the seasonal shift of fishing grounds is needed before stable and economic catches can be predicted for trawl fishery in these areas.

5.2 Important commercial fishes for trawl fishery

Most species of commercial importance are listed in Tables III, IV and V. Among them, red snappers are the most important from the viewpoints of both quantity and market value. Bigeye snapper, threadfin snapper, jacks and scad, etc. are also caught in large numbers. Naked-headed sea bream, thick-lip grunt, white snapper, grouper, etc. are also main objects of trawl fishery because of good market demand. However, red snappers are not as important in the shallow areas of coastal waters as golden snapper and some small sized species such as croaker and shad.

Commercial ichthyofauna in areas V and M are considerably different from those of the other areas. In area V, lizardfish and butterfish constitute a large part of trawl catch. While sea bream (*Taius tumifrons*) is one of the important species of trawl catch in the East China Sea, it has not been caught in the surveyed areas except in area V. This suggests that some members of ichthyofauna of area V may have migrated from the higher latitude and which in turn implies that the seasonal fluctuation of catch and species composition in area V may be larger than in the other areas.

Although triggerfish occupies a high percentage in trawl catch in all the areas except area V, it has little economic value at present. In some Southeast Asian countries, this species is treated as scrap fish (Anonymous, 1967). Threadfin (*Polydactylus*), one of the most expensive fishes in the Southeast Asian countries, has never been caught by CHANGI. It appears that the distribution of the fish may be restricted to shallower and less saline waters with muddy bottom.

5.3 Trend of demersal fish resources

As far as the data is concerned, catch per hour in 1970–72 was higher than that in 1960–62 in 4 areas out of 5 areas examined, thus superficially suggesting that resources for trawl fishery have increased during this ten years' time. However, fishing efficiency of HAI-CHING and CHANGI may be different, since the factors affecting it may differ by boat as has been mentioned earlier. Furthermore, the catch per hour in each area is to certain extent subject to a seasonal fluctuation, and some areas were operated by the two vessels in different seasons.

Therefore, the results presented in 4.2 may indicate the trend of demersal fish resources only approximately. So, it may be safer to say that the resources for trawl fishery in the surveyed areas of the South China Sea in 1970–72 were almost at the same level as those in 1960–62. As for area G (Gulf of Thailand), it may be probable that fisheries resources have been decreasing due to the recent rapid increase in fishing effort of Thai trawlers.

The difference in species composition between both periods was very remarkable except in area G, although the coefficients of correlation in ranking of the ten species were rather high in areas V, C and G. Even supposing that this result reflects actual changes in demersal ichthyofauna, they are rather desirable ones. Because, the percentages of esteemed fishes such as red snapper, thick-lip grunt and grouper had become higher in almost all the areas. Besides the above 3 species, white snapper and naked-headed sea bream which comprised only 0.3% and 0.03% of total catch in 1960–62 (all areas combined) usually occupied about 4% and 5% of total catch in 1970–72, respectively, although these fishes are put into "others" in Table XII.

It is, however, considered that this difference in species composition is also superficial to some extent. As mentioned in 4.1, very few fish species were named in the trawl catch obtained in many individual blocks by HAI-CHING. Most of them were grouped in the category "mixture". White snapper, naked-headed sea bream and triggerfish are recorded only in 4, 1 and 1 blocks respectively in Tseng's report, although these constituted frequent and abundant species in the trawl catch by CHANGI. From these facts, it may not be erroneous to judge that these species and sometimes even red snapper, thick-lip grunt and grouper are included in "mixture of high grade fishes" or in "mixture of medium grade fishes". The difference in the type of trawl net by boat might have also affected the species composition of catch.

To conclude, there is no evidence to consider that any drastic change had occurred in resources for trawl fishery in the South China Sea during the period from 1960 to 1972. The change, if any, may be a rather desirable one.

5.4 Utilization of discarded fish

Non-marketable fish caught by CHANGI were discarded on the spot. Except in area M, the discarded fish normally constituted only about 10% of the total catch. On a few occasions, particularly in shallow waters, the discarded fish were caught in large quantities, and at times exceeding the catch of marketable fish. Such a case was observed in area M in July 1971 when the discarded fish were 1.4 times the amount of marketable fish.

According to the result of the joint Thai-Malaysian-German trawl survey along the east coast of the Malay Peninsula (Anonymous, 1967) the ratio of scrap fish to food fish was about 3:5. In their study, leiognathids and gerrids were regarded as fish suitable for human consumption while triggerfish were considered as scrap fish. However, in CHANGI the former two species were discarded and the latter was landed.

Silverbelly (*Leiognathus*) and silver-biddy (*Pentaprion*) were the commonest and most abundant discarded species of CHANGI. These fishes were regarded as food fish in Thailand and Malaysia, and they are valuable material for making fish sauce in Vietnam (Vien, 1968). It has been suggested that these fish may serve as bait for tuna fisheries, either frozen for tuna long line or live for pole and line, as well as bait for bottom long line.

5.5 Future investigations

Very little has been published on the fishery biology of demersal fish in the region. In order to establish a suitable trawl fishery and the management of fishery resources of the Southeast Asian region, some aspects of fishery biology such as spawning, growth, migration, habitat, population density, etc. need to be considered. However, priority should be given to the economic studies of the most appropriate size of fishing boat and fishing techniques for the exploitation of the various fishery resources in the region. These must be considered objectively, using experimental catch data and the actual market condition and demand in each member country.

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Studies on the Feeding Habits of Red Snappers, *Lutjanus Sanguineus* and *L. Sebae*

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Abstract

Examination of stomach contents were carried out on 276 *Lutjanus sanguineus* and 129 *L. sebae* in an attempt to study the feeding habits of the two commercially important demersal fishes occurring in the southern South China Sea.

The studies show that although their feedig habits are rather flexible, their diet consists mainly of fishes; crustaceans (especially crabs and stomatopods) and cephalopod molluscs. The result of the present study is in general agreement with the diet of other *Lutijanus* species from different areas as reported by some workers. However, the data presented here are rather different from the diet of *L. sauguineus* in the Tonkin Bay (Vien, 1968)

The feeding habits of both species are well suited for a demersal life, and they occupy the highest niche in the bottom ichthyofauna in the South China Sea.

The reaction between the regurgitation rate and the depth of the fishing ground as well as the regression of stomach length against the total length of fish were also determined.

1. INTRODUCTION

Red snappers hold a very important position in the trawl fisheries particularly in the South China Sea, usually occupying more than 20% ofthe total catch. Among the red snappers belonging to the genus *Lutjanus*, *L. sanguineus* (Cuvier et Valenciennes) is the most important, often exceeding 70% of all red snappers caught by trawl (Kungvankij, 1971). Its usual size in trawl catch is between 55 and 70 cm in total length and 2 and 4 kg in body weight. *L. sebae* (Cuvier et Valenciennes) is of second importance. Although its average total length is about the same as *L. sanguineus*, it is heavier because of its relatively deeper body.

While there is considerable literature on ichtyofauna and trawlfisheries of the South China Sea and its adjacent waters, very little deals with the biological and ecological aspects of commercially important fishes. Vien (1968) referred briefly to the feeding habit of *L. erythropterus* Bloch (= *L. sanguineus*) in the Tonkin Bay while Helfrich et al (1968) and some other workers reported the feeding habits of some other species of the genus. In view of the limited information the Marine Fisheries Research Department of the Southeast Asian Fisheries Development Center has drawn up a program to study the various biological aspects of economically important demersal fishes in the Southeast Asian region. The present paper deals with the feeding habits of the two red snappers.

2. MATERIALS AND METHODS

The material fish were collected by the research vessel CHANGI during the period between April and September, 1971, in the southern part of the South China Sea. The stomach contents of 276 *sanguineus* and 129 *sebae* were examined. The stomach was exposed by making a mid-ventral incision in the body wall, usually within 15 minutes after the catch was emptied onto the deck. The stomach was cut off anteriorly from the esophagusand posteriorly from the intestine behind the pyloric valve, removed and tightened at both ends. To each stomach, an index number was attached with thread and preserved in 10% formalin solution to prevent any further digestion and decomposition of the contents. The total length, body weight, sex, sexual maturity of the fish were recorded together with the catch record. Any other non-marketable organisms caught with the fishes as well as parasites infestation were also noted.

Examination of the stomach content was done in both the laboratory and on board CHANGI. After dissecting, the content of the stomach was discharged into a glass

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