SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
TRAINING DEPARTMENT
in collaboration with
Department of Fisheries
Ministry of Agriculture and Cooperatives

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MULTIDISCIPLINARY EVALUATION OF THE ARTIFICIAL REEF PROJECTS IN THAILAND
A REPORT

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January 1989

Artificial Reefs Study Team
SEAFDEC & MFD

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PREFACE

During the last ten years, artificial reefs have been installed experimentally at thirty-one sites along the coastline of Thailand. A follow-up survey of these experiments has been carried out only partially at each site. Since the artificial reef project was initiated primarily by drawing on the practical experience of fishermen, because of insufficient baseline data, the implication is the the study and research should be carried out from a scientific point of view in order to achieve maximum benefit from the installations.

Consequently, at the request of the Department of Fisheries, Thailand, a joint team (SEAFDEC/MFD) was formed to implement an evaluation survey. The survey was multidisciplinary and included the biological, oceanographical, engineering and socio-economic aspects of artificial reefs.

This report is a compilation of the preliminary research results obtained by the members of the survey team and includes their recommendations.

T. Bhukaswan

Thiraphan Bhukaswan
Secretary-General

2. Objectives

(1) To evaluate the effectiveness of the existing artificial reefs installed by the Thai Department of Fisheries in the Gulf of Thailand;

(2) To study the scientific aspects of artificial reef module forms, materials used, reef design and maintenance; and

(3) To study the socio-economic impacts of artificial reefs upon small-scale fishing communities.

3. Project Team Composition

Project Leader
Mr. WAJIRO FUJISAWA

Coordinator
Dr. VITHYA SRIMANOBHAS
(MFD)

- Engineering Survey team (S/T)
  - Leader: Mr. W. FUJISAWA
  - Member: Mr. SUJIN SAE-UNG
- Biology S/T
  - Leader: Dr. SRIMANOBHAS
  - Member:
    - Dr. HIROYUKI YANAGAWA
    - Dr. CHITTIMA ARYUTHAKA (MFD)
    - Mr. RONNAACHAI MOODREE (MFD)
    - Mr. AUSSANEE MUNPRASIT
    - Mr. SANTEE SUNGTHONG (EMFDC)
    - Mr. SUJIN SAE-UNG
- Oceanography S/T
  - Leader: Mr. AUSSANEE MUNPRASIT
  - Member:
    - Mr. SUPACHAI ANANPONGSUK
    - Ms. SUMITRA RUANGSIVAKUL
- Socio-Economics S/T
  - Leader: Mr. HIROAKI YONESAKA
  - Member: Mr. TDOEY SIKACHA

MFD : Marine Fisheries Division, Department of Fisheries, Thailand
EMFDC: Eastern Marine Fisheries Development Center, Rayong, Thailand

4. Site Selection

During the last 10 years, artificial reefs have been installed experimentally at 31 sites in 8 areas along the coast of Thailand.

The modules used for the artificial reefs were made from many different materials and were of various shapes.

To carry out an evaluation survey of the artificial reefs a number of sites were selected and each site was surveyed three times over a period of 6 months.

Rayong and Petchaburi were chosen as suitable sites for the survey at a conference attended by the leaders from MFD and SEAFDEC (Fig. 4-1 & 2).

Off Rayong, artificial reefs had been installed in 8 sites. From these 8 sites, one site was selected after confirmation of the existence of the reefs using an echo-sounder.

This work was carried out between the 24th and 26th November 1987 using BAMPHE15 a survey vessel belonging to the Eastern Marine Fisheries Development Center (EMFDC) and a FURUNO FE-600A echo-sounder.

From the results, we could confirm the existence of reefs at 7 sites out of the original 8, especially at Nos. 5 & 6, where we were able to make underwater observations and a Video recording.

At No.6 we found more modules than at any other site, and chose this site to conduct the evaluation survey.

As for No.1, the area was dredged with an anchor, but no modules were found. We assume that the modules have been broken up by the action of the sea and dispersed.

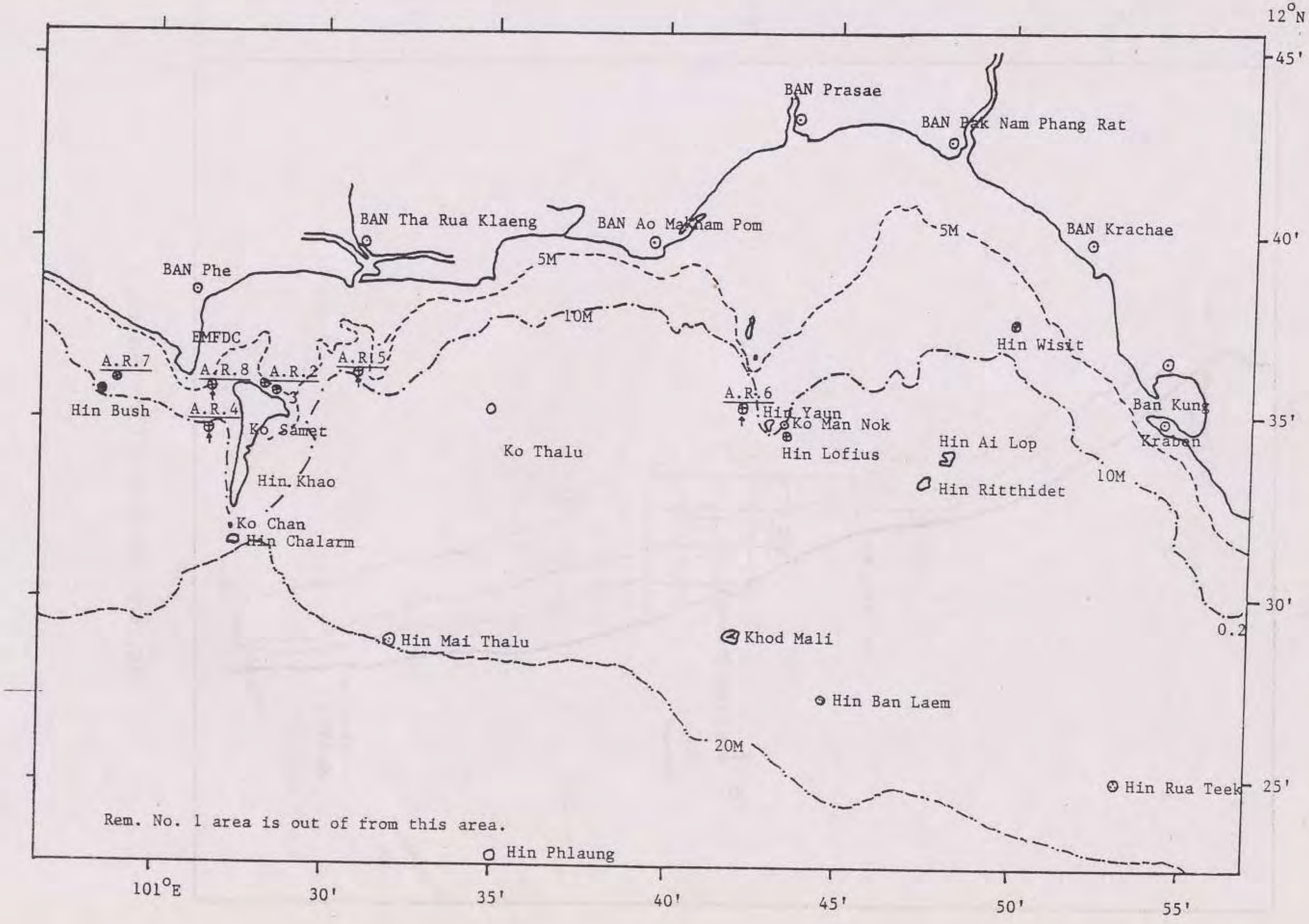


Fig. 4.1 Installation Sites off Rayong

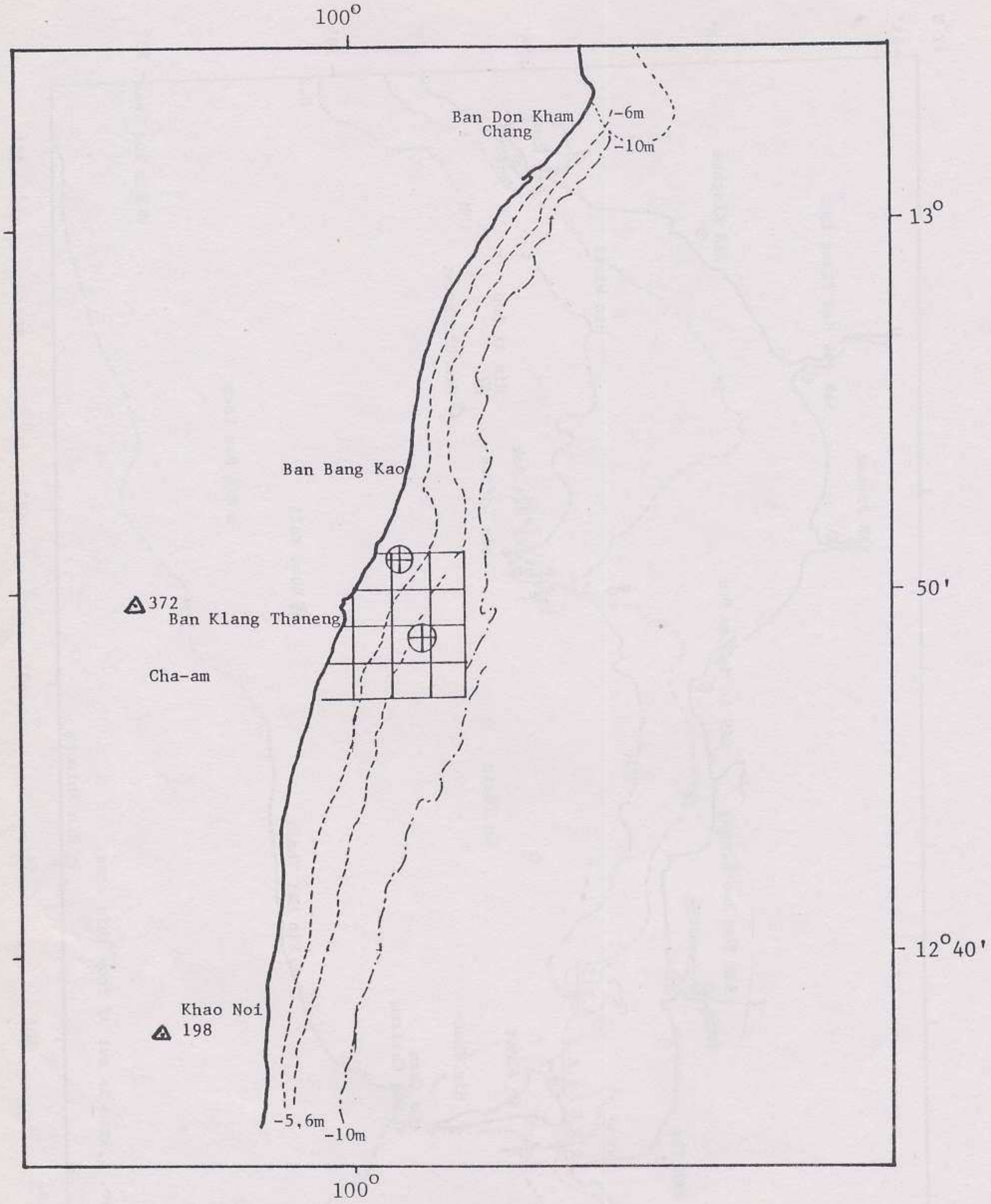


Fig. 4.2 The site off Petchaburi

5. Survey Record

	1987		1988												1989	
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Rayong Survey	1**		2**				4**	6**								
Petchaburi Survey	1**			3**			5**									
Data analysis							++++	++++	++++	++++ ^1	++++					
Description (Report)											****	****	****	**** ^2		
Monsoon	<- Northeast Wind ->			<--------			Southwest Wind			-------->						

1. Confirmation of the existence of modules (Petchaburi could not be confirmed due to bad sea conditions)

2. 25-29 Jan.
3. 1-5 Feb.
4. 9-13 May
5. 23-27 May
6. 11-18 June

[^1 Progress report
^2 Report should be presented]

6. Methodology

The surveys and research listed below were undertaken in Rayong and Petchaburi Provinces.

1) Engineering Research

   (1) Natural reef survey
   (2) Experiments using miniature modules in a water tank (SEAFDEC/TD)

2) Oceanographical Research

   (1) Physical Survey
   (2) Chemical Survey

3) Biological Research

   (1) Observation and Survey
   (2) Benthic Community Survey
   (3) Stock Evaluation Survey

4) Socio-Economics Research

   (1) Sociological Survey
   (2) Economic Research
   (3) Policy Research

7. Results and Discussion

7.1 Engineering Research (by W. Fujisawa)

Introduction

The required functions of artificial reefs are as follows:

(1) To act as a food seeking ground for fish
(2) To provide shade

(3) To act as a refuge, and
(4) In some cases, to induce eddies, upwellings and cause vibrations.

As yet, it is not clear which of the functions listed above is the most effective, however, it is known that marine life congregates around natural reefs for breeding and feeding. This phenomenon is well known to local fishermen and from their experience they know when and what kind of fish (species) will congregate at a reef site.

Based on the experience of local fishermen, this survey was carried out at an effective natural reef near Rayong Province. From the results, we selected the most useful features and incorporated them into the design of the modules for the artificial reefs.

Methodology

7.1.1 Natural reef survey

The most useful and effective natural reefs found in the waters off Rayong province were selected after interviewing the local fishermen, and measuring the length, width and height of the reefs using an echo sounder.

7.1.2 Experiments using the water tank

Experiments were carried out using the water circulating tank at SEAFDEC/TD (Fig. 7.1.1). Miniature models were used for the experiments. The shapes of the models were similar to those which are actually installed in the Gulf of Thailand, i.e., connected tyres and concrete block cubes. Furthermore for the basic shape, we used a column, a square pillar and a triangular pillar.

The following two experiments were carried out using these miniature models.

a. Each model was placed in the current to observe the changes in the current behind the model which were recorded with metylene blue for visualization of the current.

b. Sand was placed on the tank floor and the models were placed on it in order to observe the effect on the models of the movement of the sand by the current.

Based on the data obtained from these experiments, the most suitable and workable artificial reef module was designed.

Results

(1) Natural reef survey

Some target reefs were selected after interviewing fishermen at Ao Makhampom. According to the fishermen, who were selected by the chairman of the Fishery Cooperative Association at Ao Makhampom, the most effective reefs are distributed between Man Klang Island and Man Nok Island. We, therefore, chose this area to conduct the investigations using a fishfinder.

The survey areas and the route of the cruise are shown in Figs. 7.1.2 and 7.1.3.

The fishfinder recording is also shown in Fig. 7.1.4.

As seen from the recording, this area is studded with small natural reefs. The reasons for this are due to changes in sea level which occurred about 18,000 years ago and will be described later. The sizes of the natural reefs are, maximum height 2-2.5 m, width 2-3 m.

(2) Experiments using the water-circulating tank

Seven small-scale models were used for the experiment. Each model is shown in Fig. 7.1.5 (diminished scale is 1/10).

a. Visualization of current

In general, when carrying out a hydraulics model test, we must apply the law of similarity to the Frude Number. If the geometric diminishing scale is 1/s, the current speed for the tests should be applied as $1/\sqrt{s}$ the current speed at site. Following this rule, we fixed the current speed at 10 cm/sec. The actual current speed obtained At Phetchaburi was 39 cm/sec. (maximum current speed).

Two typical results are shown in the photographs (Fig. 7.1.6). The difference between these two models is that only the connected tyres have some inner space and make a complicated form. Specifically, the backward current changed complexly (Fig. 7.1.6 i-j). In the case of the pillar, the current separated into two parts around the pillar and formed eddies. These eddies disappeared behind the pillar, roughly at a distance of four times the diameter of the pillar.

b. Sand floor (turnover, corrosion)

The Medium grain size sand sifted from the river sand after being washed was about 0.36 mm. The current speed was set at 23 cm/sec., because at 10 cm/sec., as used in the visualization, there was no sand movement. At the faster speed, the sand began to move.

The models provided were: column, square pillar, connected tyres and a concrete block cube which was open at the top and closed at the base.

Within half an hour, the following observations were made:

* The sand had started to move at the front corner of each model.

* The sand movement at the leading edge of the models, especially of the column and square pillar models, caused undermining and the column and square pillar collapsed into the hole. This phenomenon did not happen with the connected tyres and concrete block cube models.

* The connected tyres only leaned toward the current, but the concrete block cube with the sealed base remained stable, although undermining occurred up to 1/2 of its length.

Photos of typical results are shown in Fig. 7.1.7.

Discussion

The artificial reef is one of the technological innovations to enter the ocean ecosystem to increase fishery resources. Prior to setting up an artificial reef, we have to understand the ecosystem correctly based on data relating to the underwater topography, water-mass covering the sea-bed and the pattern of biocoenosis, then we must consider the technical aspects. Emphasis should be placed on the biocoenosis, not the grouping of species but the individuals of one species in a given area. The features of each species will be shown by the living pattern of each species.

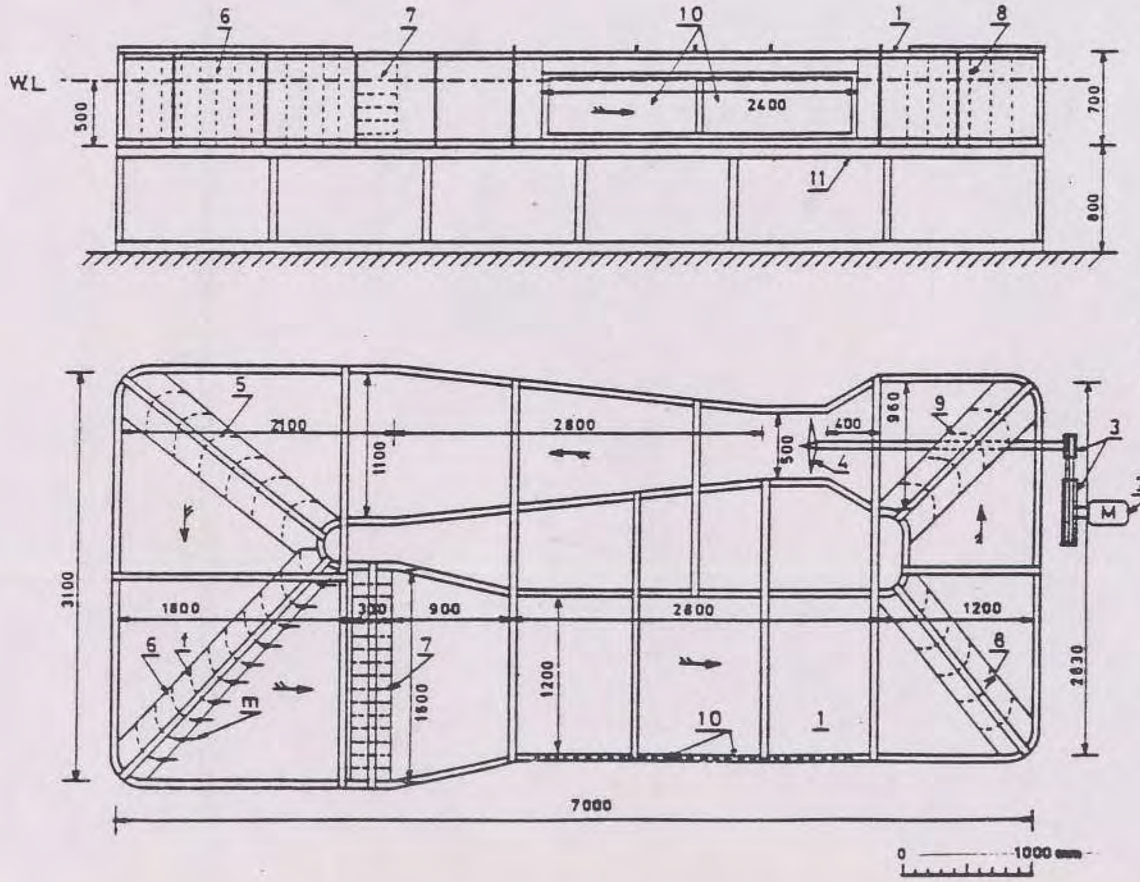
The actual number of artificial reef projects in the tropical zone is less than in the temperate zone. Because of fewer experiences, the data available are insufficient for the development of artificial reef projects, therefore, we have to discuss these projects referring to experiences in the temperate zone. Here, the analysis will be done based only on the underwater topography from an engineering point of view. From the result of this analysis, we would like to clarify the outline of artificial reef modules.

Generally, the slope of the sea-bed in the Gulf of Thailand is very gentle. For instance, from the chart we can read a depth of only 19 m at a spot which is 10 km offshore from Khao Plet (near Ban Phe, Rayong Province), which means a slope of less than one-thousandth. The sea-bed of the Gulf of Thailand is covered with Quaternary Sediments over 3,000 m thick (Foughn ., 1963). When we make detailed observations of the sea-bed, we can find some variations on it, i.e. the existence of projections. The scale of the projections ranges from islands for the large-scale to small underwater projections for the small-scale. Generally, small projections which exist below the sea-surface are called natural reefs. The mechanism of the existence of these projections can be explained well by the study of geography.

During the glacial period which occurred about 17,000-18,000 years ago, much of the Northern Hemisphere was covered with great ice sheets and the sea level dropped to a depth of 130-140 m (Daly, 1934, Minato, 1980). At this time, the Gulf of Thailand may have become land due to the drop in sea level. This land was eroded by river currents, and valleys were formed here and there. During the following interglacial period, the sea level rose to its present level, and the Gulf was covered with sea water. In this period, the valleys were gradually filled in with earth and sand leaving some higher areas as natural reefs or islands. We found that these natural reefs are only about 2-2.5 m in height from the sea-bed.

It has been stated in the introduction to this section of the report that areas where natural reefs exist are productive fishing grounds. On the other hand, to make the mechanism of this phenomenon more ecological, investigations and studies are needed.

However, from the results of the natural reef survey, we are considering making a module similar in scale to the natural reefs, in other words, 2-2.5 m in height and 2-3 m in width.



1. Body of water tank
2. Stepless transmission motor
3. V-belt (3 belts, 3:1)
4. Propeller
5. Regulator with fixed panel
6. Regulator with moveable panel and fixed panel
   m : Moveable panel
   f : Fixed panel
7. Latticed regulator
8. Regulator with fixed panel
9. Regulator with fixed panel
10. Observation glass window
11. Base

← Direction of current

SEAFDEC TRAINING DEPARTMENT		
WATER CIRCULATING TANK FOR TESTING MODEL FISHING GEAR		
	Design	Drawing
Name	Yozo Tawara	Yozo Tawara
Date	15/7/78	5/8/78

Fig. 7.1.1 General Arrangement of the Water Circulating Tank

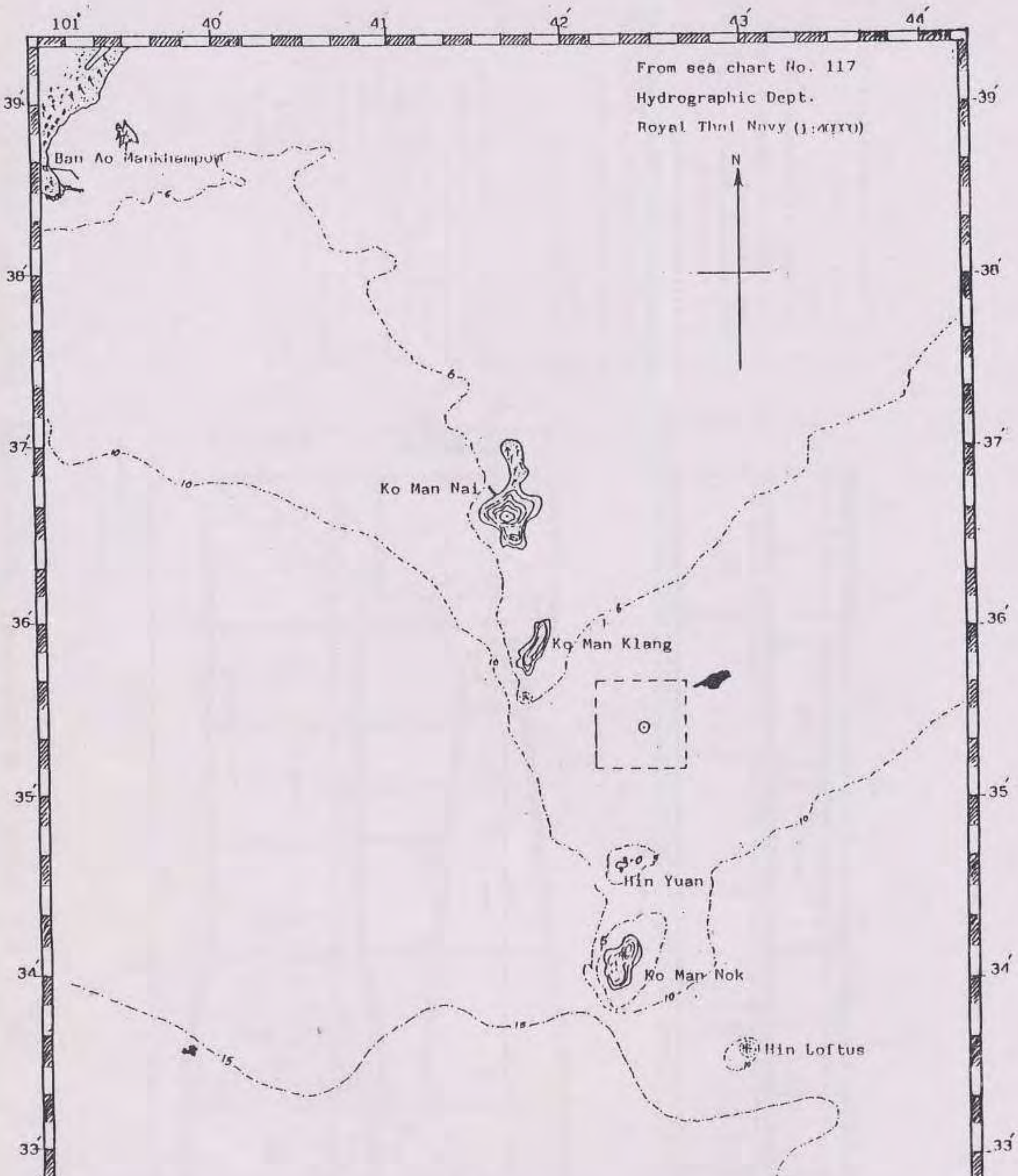


Fig. 7.1.2 The survey area

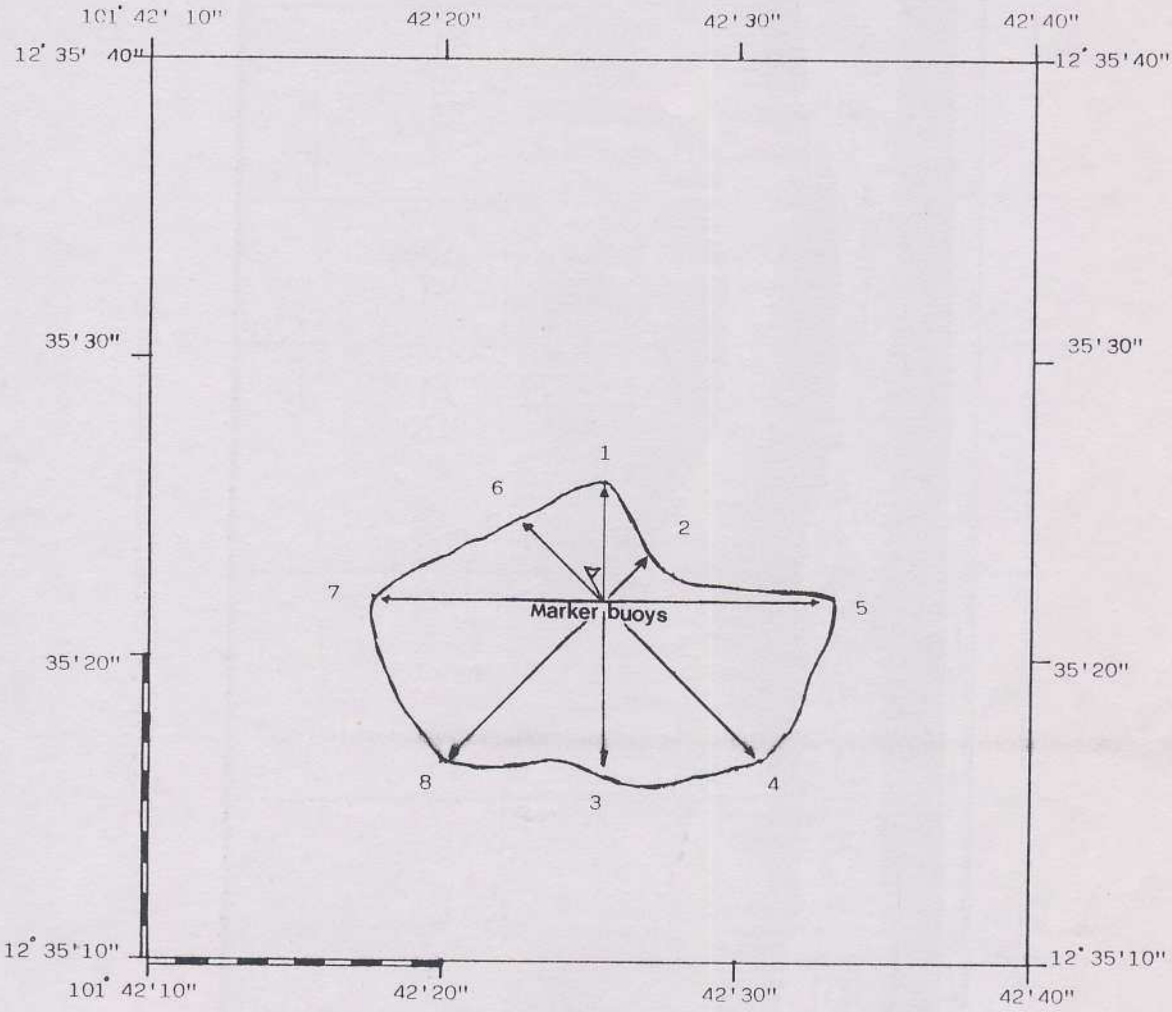


Fig. 7.1.3 The route of the cruise

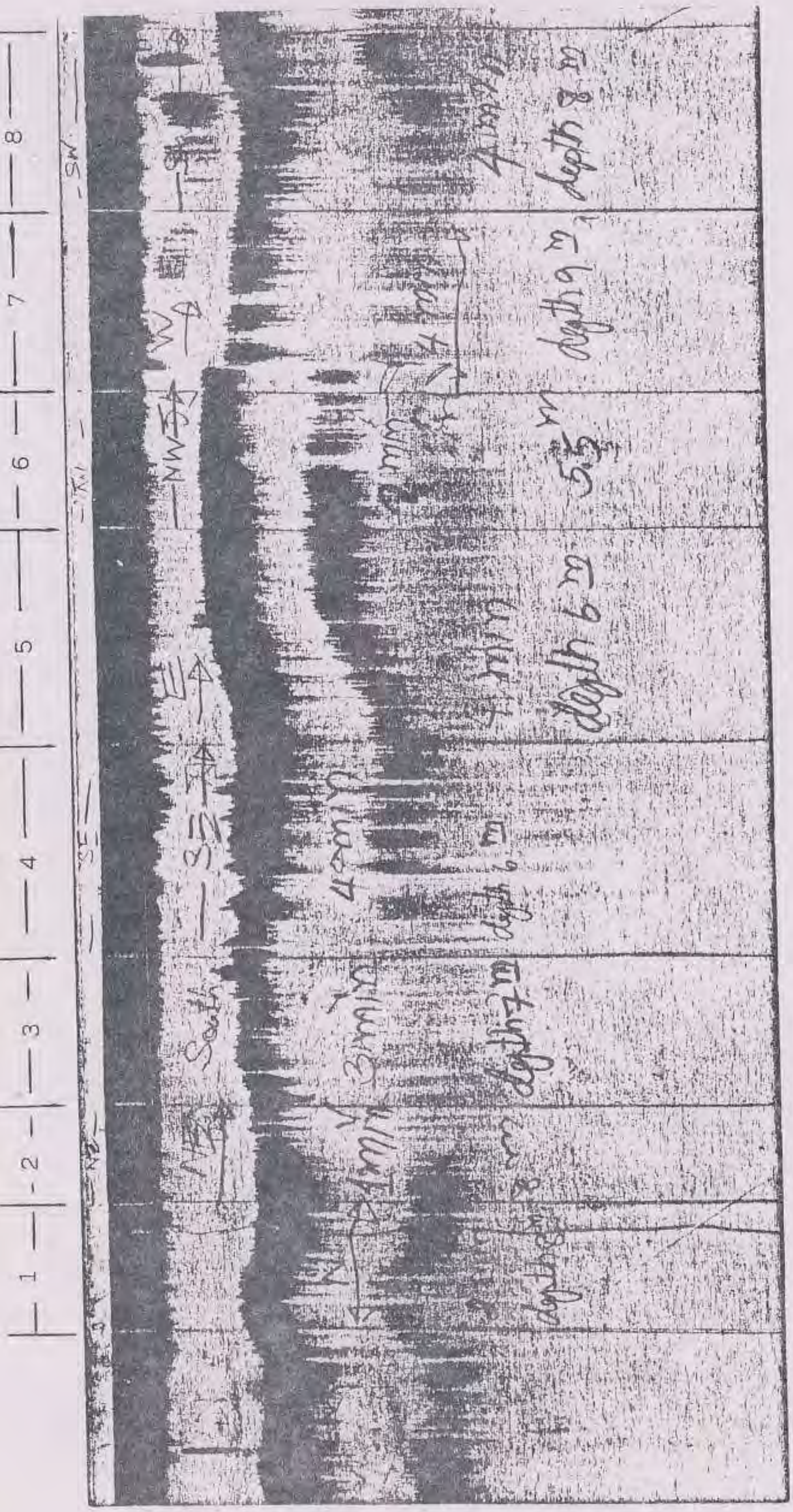


Fig. 7.1.4 Fishfinder Recording

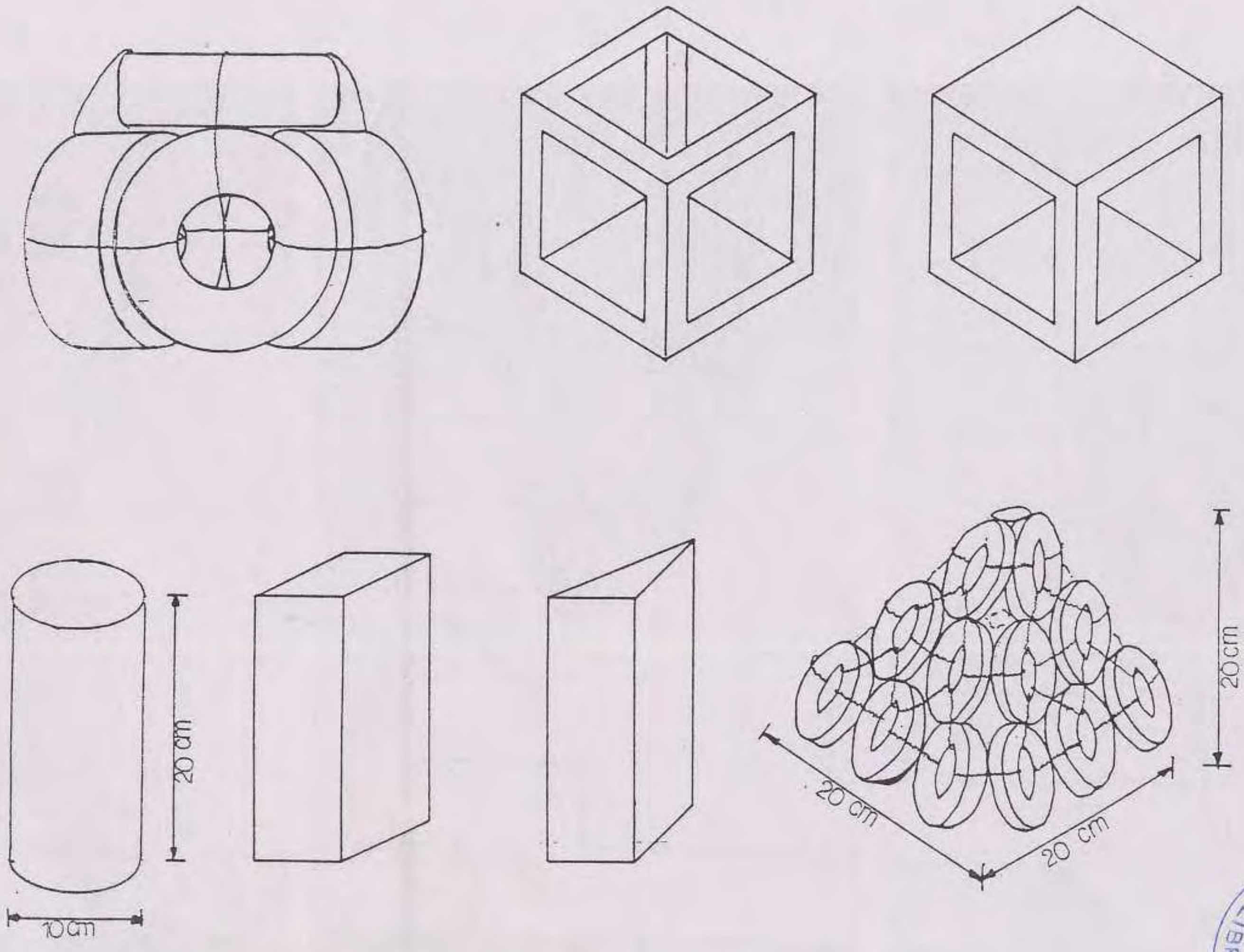
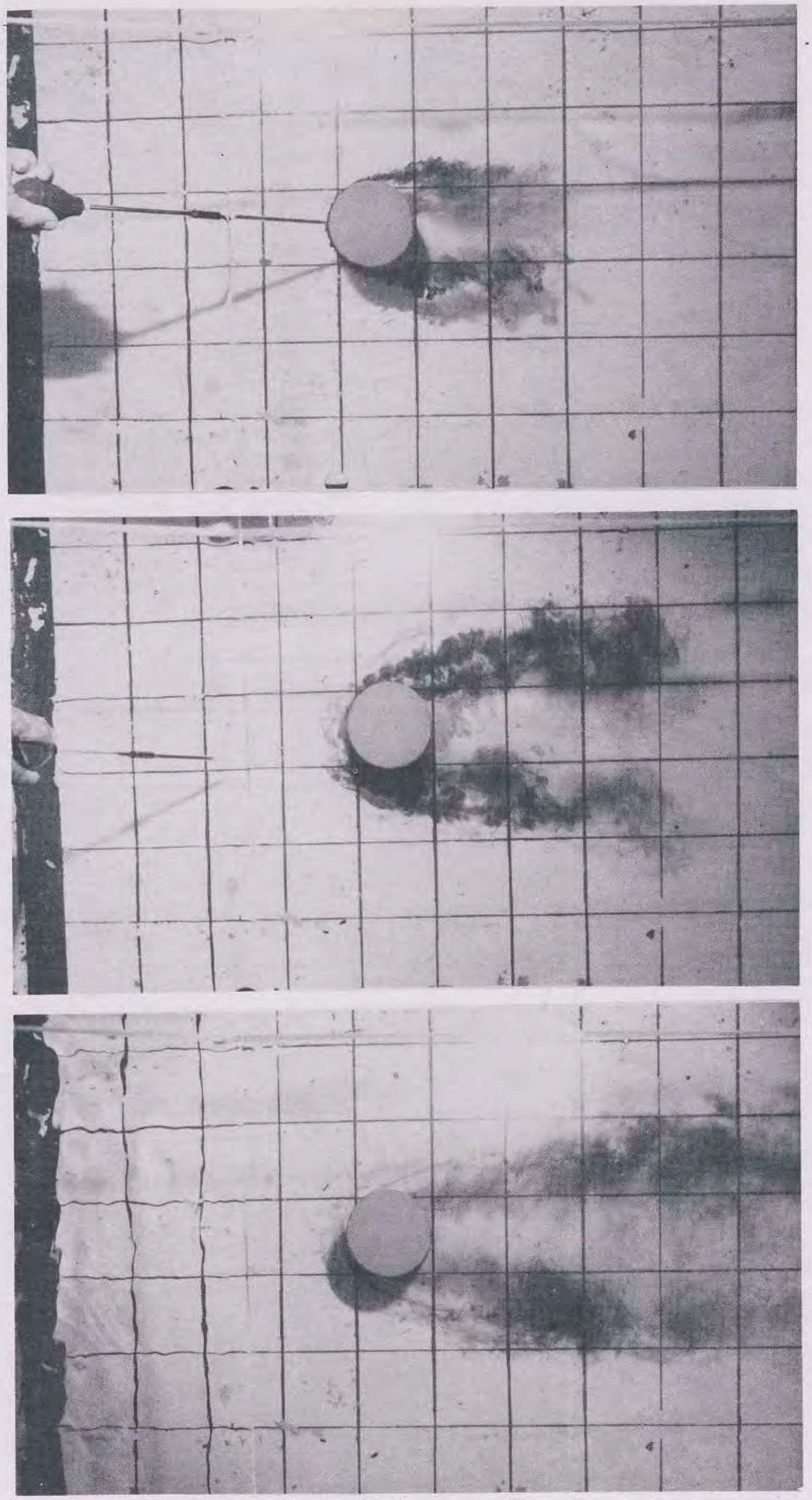


Fig. 7.1.5 Seven Miniature Models

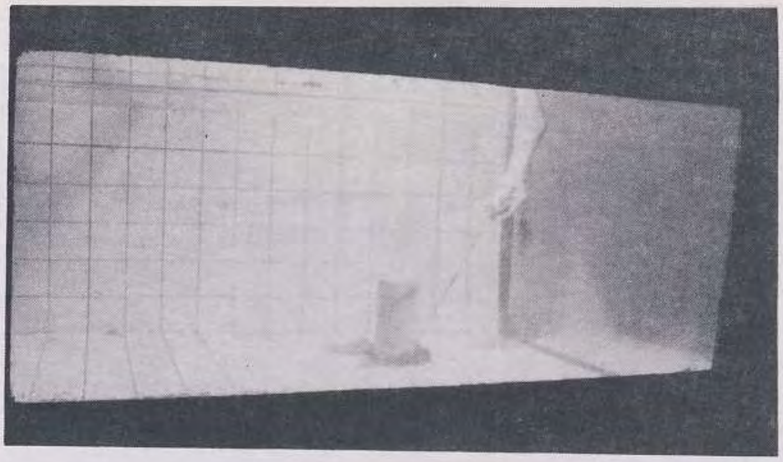


(a)

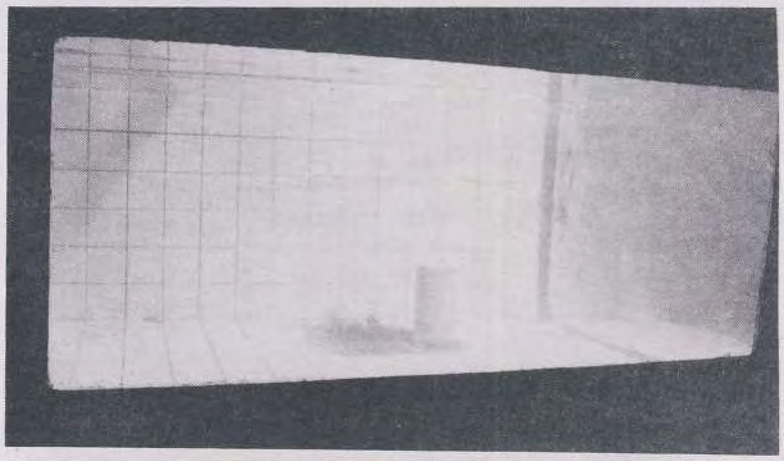
(b)

(c)

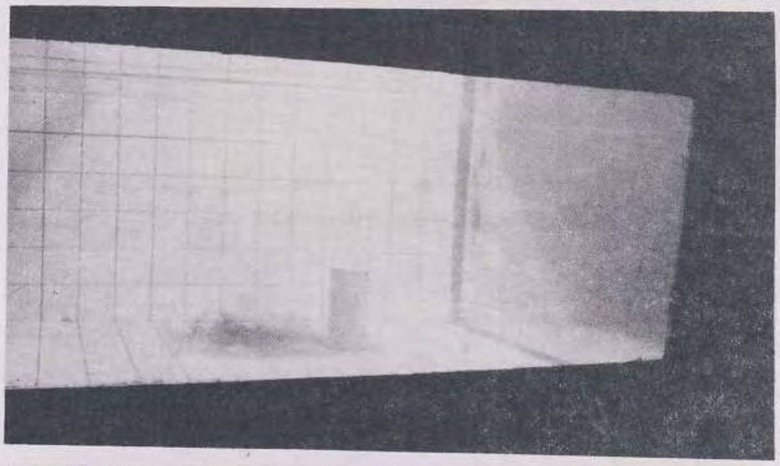
Fig. 7.1.6 The Backward Current Change
a-c Column, top view (current flow from left to right)



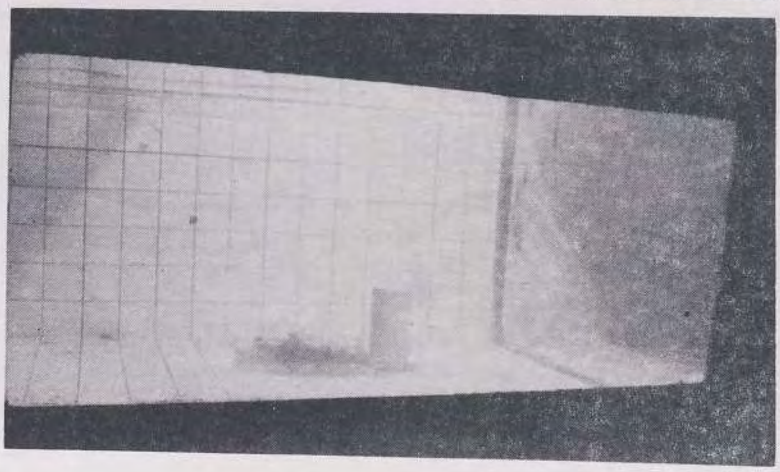
(d)



(e)

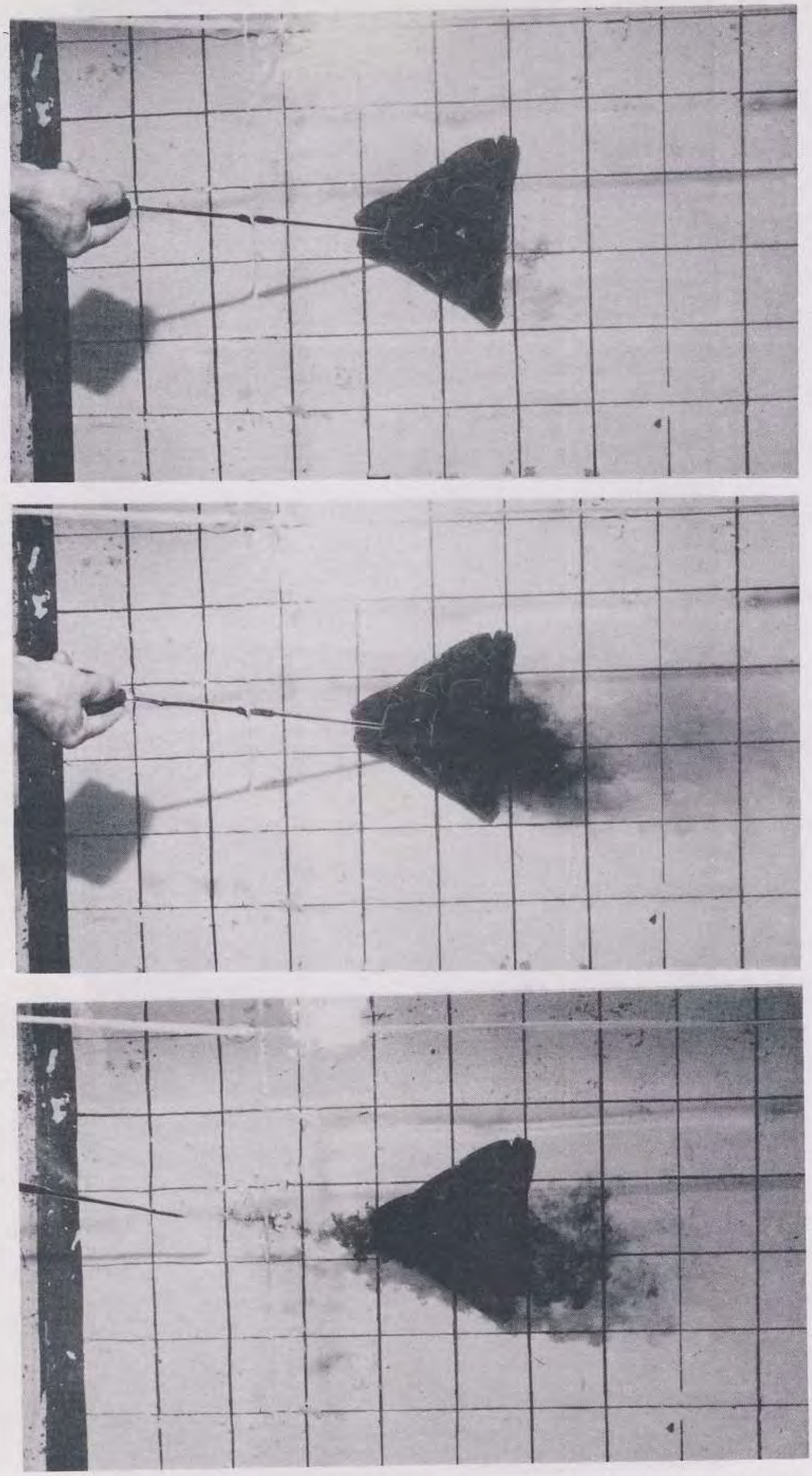


(f)



(g)

d-g Column, side view (current flow from right to left)

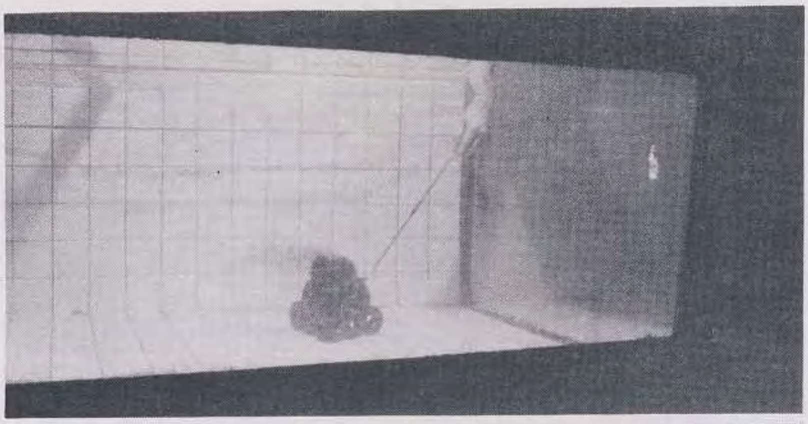


(h)

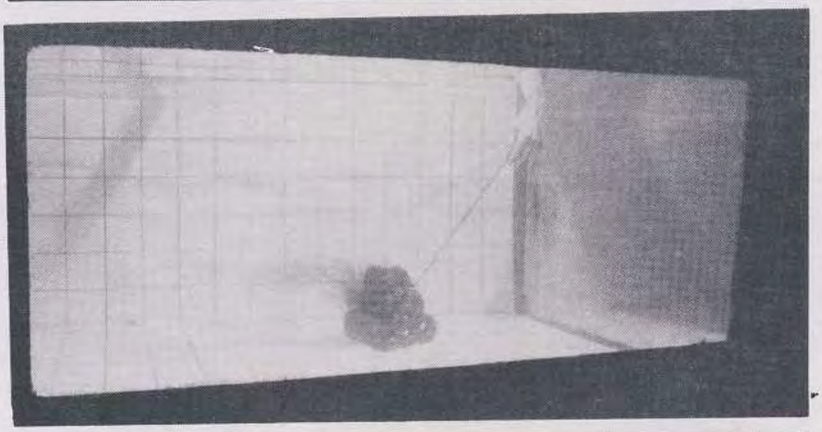
(i)

(j)

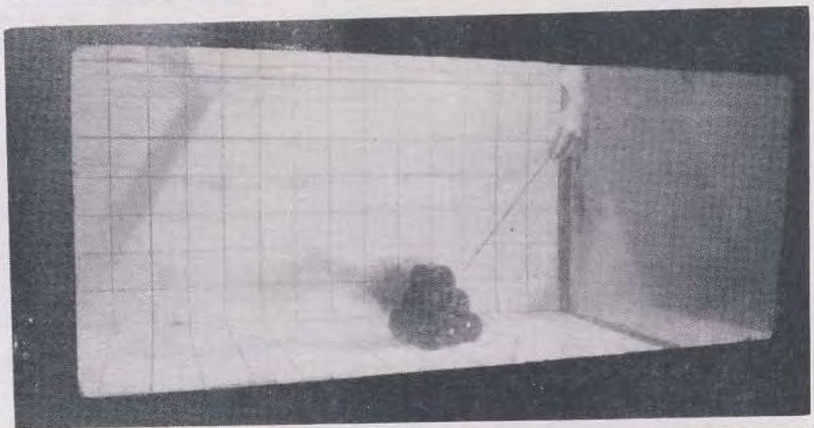
h-j Connected tyres, top view (current flow from left to right)



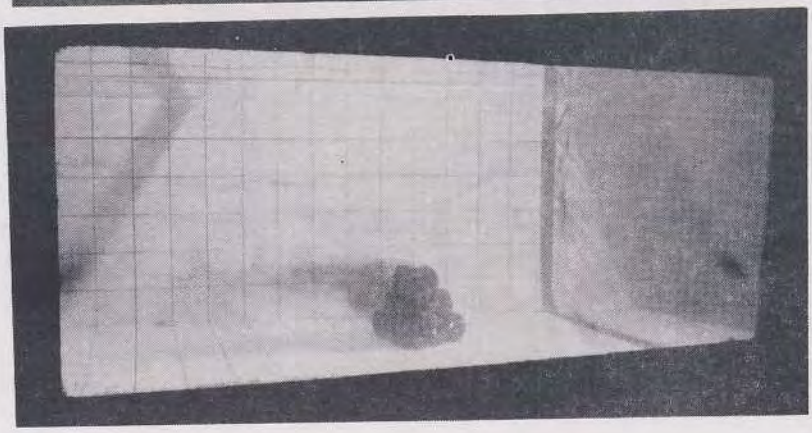
(k)



(l)

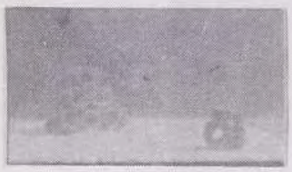


(m)

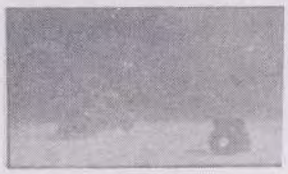


(n)

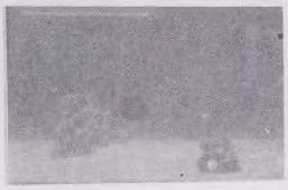
k-n Connected tyres, side view (current flow from right to left)



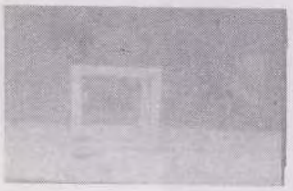
start



after 30 minutes



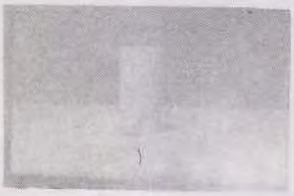
after 1 hour



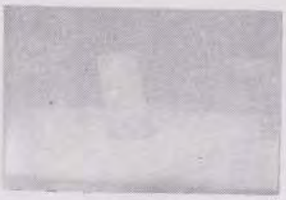
start

erosion can be observed under corner

after approx. 30 minutes



start



after approx. 10 minutes

after 13 minutes

Current direction is from left to right

Fig. 7.1.7 Photographs of sand floor

7.2 Oceanographical Research

7.2.1 Physical Survey (by S. Ananpongsuk)

Introduction

The first artificial reef selected for surveying was "Artificial reef No.6" off Rayong Province, 4000 m north west of Koh Man Nok at a depth of 17-18 meters, (Fig. 7.2.1.1). The second artificial reef selected was off Petchaburi Province on the west coast of the Gulf of Thailand. This reef was installed in 1985 off Cha-Am district beach at a depth of 5-7 meters, (Fig. 7.2.1.2). Two positions were set at each of the survey sites, one in the middle of the reef and the other about 1,000 meters beyond the reef site.

Materials and Methods

The current was monitored at a level 2 meters above the bottom continuously 24 hours with a DPCM-4 (Digital Printer Current Meter). Both the current direction and speed were recorded. The field survey for gathering the data was conducted as follows:

25-30 January 1988

The first survey was made at the Rayong reef site. The current was observed in two positions and other oceanographic data such as, water temperature, transparency, salinity, sediment, grain size and water quality were collected in six positions for determination of the dissolved oxygen and nutrient compounds i.e. nitrate, nitrite, ammonia, phosphate and silicate. (also see section 7.2.2 chemical survey).

1-5 February 1988

The reef site off Petchaburi, the current was measured in one position only at the center of the reef. Oceanographic data were obtained in a few positions.

9-13 May 1988

The current was measured twice in the center of the reef and once outside the reef.

23-27 May 1988

During the second field survey at the artificial reef off Petchaburi Province, current measurement data were obtained from two positions, one in the center and one outside the reef area. Oceanographic sampling was carried out in six positions.

13-17 June 1988

The final survey for this project was at the reef site off Rayong Province. The current meter was positioned in two areas and readings were taken. Oceanographic data were obtained in six positions.

Results

Observation data obtained from the field survey: The results for each position were as follows:

Rayong Province

Position	Date	Max. speed cm/sec.	Ave. speed cm/sec.	Estimated dir. degree
A. Center of reef	26-27 Jan. 88	9.0	6.1	225
	10-11 May 88	13.0	9.0	242
	12-13 May 88	11.0	6.5	081
	14-15 June 88	18.0	13.4	046

Position	Date	Max. speed cm/sec.	Ave. speed cm/sec.	Estimated dir. degree
B. Outside of reef	27-28 Jan. 88	9.0	4.8	033
	11-12 May 88	14.0	7.2	087
	15-16 June 88	19.0	13.4	357
Petchaburi Province				
A. Center of reef	2-3 Feb. 88	37.0	20.1	033
	24-25 May 88	31.0	18.9	087
B. Outside of reef	25-26 May 88	25.0	14.9	357

Note: 1. The observations were made six times every hour over a 24 hour period, i.e. 144 times in each survey.

2. The observations on 12-13 May 1988 were made once in a 23 hour - period only.

Discussion

The current's direction histograms and N-component and E-component curves were monitored in each position, (Fig. 7.2.1.3 to 12). This could not predict the current time series variation of movement. It only showed the magnitude and the direction of the current, (Fig. 7.2.1.1 to 10). The average magnitude of this observation was not too high. The results showed that the magnitude of the current is suitable for the setting up of an artificial reef, (Chang 1984, the current speed which passes through an artificial reef installation site should not be more than 77.22 cm/sec.). The maximum average magnitude in each survey was not over half of that allowable. The speed the current passes through the reef area was not significant in either location. The estimated current direction at the two sites was: Rayong Province northeast ⇄ southwest and southeast Petchaburi Province northwest ⇄.

Table 7.2.1.1 Current measurement records at station No.1 Rayong Province (26-27 January 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
0930	251	7	-2.83	-6.62
1030	129	6	-3.77	4.66
1130	129	8	-5.03	6.22
1230	102	7	-1.46	6.85
1330	88	8	0.28	7.99
1430	83	7	0.85	6.95
1530	337	6	5.53	-2.35
1630	323	6	4.79	-3.61
1730	310	7	4.5	-5.36
1830	210	8	-6.93	-4
1930	194	7	-6.79	-1.69
2030	210	6	-5.2	-3
2130	246	6	-2.44	-5.48
2230	219	5	-3.88	-3.14
2330	254	6	-1.66	-5.77
0030	234	5	-2.94	-4.05
0130	244	5	-2.19	-4.95
0230	233	6	-3.61	-4.79
0330	236	5	-2.79	-4.15
0430	237	5	-3.01	-4.19
0530	233	5	-3.47	-3.99
0630	226	5	-3.53	-3.59
0730	225	5	-2.24	-3.53
0830	236	4	4.3	-3.32

Table 7.2.1.2 Current measurement records at station No.1
Rayong Province (10-11 May 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
1100	32	10	8.48	5.30
1200	313	9	6.14	-6.58
1300	119	8	-3.88	7.00
1400	170	9	-8.87	1.57
1500	116	9	-3.94	8.09
1600	308	9	5.54	-7.09
1700	281	9	1.72	-8.84
1800	317	11	8.04	-7.50
1900	268	11	-0.39	-11.0
2000	305	11	6.31	-9.01
2100	265	10	-0.87	-9.96
2200	295	9	3.81	-8.15
2300	298	8	3.75	-7.06
0000	324	7	5.66	-4.12
0100	345	7	6.76	-1.81
0200	109	8	-2.61	7.57
0300	106	8	-2.21	7.69
0400	106	9	-2.48	8.65
0500	94	8	-0.56	7.98
0600	187	8	-7.94	-0.98
0700	187	9	-8.94	-1.10
0800	125	10	-5.74	8.19
0900	144	9	-7.28	5.29
1000	161	8	-7.57	2.61

Table 7.2.1.3 Current measurement records at station No.1 Rayong Province (12-13 May 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
1500	46	6	4.17	4.31
1600	97	7	-0.85	6.95
1700	97	6	-0.73	5.96
1800	85	6	0.52	5.98
1900	73	5	1.46	4.78
2000	19	5	4.73	1.63
2100	350	6	5.91	-1.04
2200	25	6	5.50	2.54
2300	174	9	-8.96	0.95
0000	185	7	-6.97	-0.61
0100	161	6	-5.68	1.96
0200	108	5	-1.54	4.76
0300	53	4	2.41	3.19
0400	118	7	-3.28	6.18
0500	104	7	-1.69	6.79
0600	109	7	-2.28	6.62
0700	126	6	-3.53	4.85
0800	97	5	-0.61	4.50
0900	28	4	3.53	1.88
1000	5	7	6.97	0.61
1100	343	7	6.69	-2.04
1200	2	11	10.99	0.39
1300	216	8	-6.47	-4.70
1400	-	-	-	-

Table 7.2.1.4 Current measurement records at station No.1 Rayong Province (14-15 June 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
1014	111	11	-3.94	10.27
1114	263	12	-1.46	-11.9
1214	345	15	14.49	-3.89
1314	351	15	14.82	-2.34
1414	63	16	7.26	14.26
1514	341	17	16.08	-5.54
1614	333	17	15.15	-7.72
1714	316	14	10.07	-9.73
1814	12	14	13.69	2.91
1914	18	15	14.26	4.64
2014	265	13	-1.13	-12.9
2114	132	15	-10.0	11.15
2214	90	9	0	9.00
2314	56	11	6.15	9.12
0014	99	10	-1.56	9.88
0114	60	11	5.50	9.53
0214	47	11	7.50	8.04
0314	46	10	6.95	7.19
0414	92	12	-0.42	11.99
0514	53	14	8.43	11.19
0614	128	13	-8.01	10.24
0714	85	15	1.31	14.94
0814	118	11	-5.16	9.71
0914	182	15	-14.9	-0.52

Table 7.2.1.5 Current measurement records at station No.6
Rayong Province (27-28 January 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
1120	25	7	6.34	2.96
1220	99	8	-1.25	7.9
1320	101	7	-1.34	6.87
1420	98	6	-0.83	5.94
1520	111	4	-1.43	3.74
1620	98	4	-0.56	3.96
1720	104	5	-1.21	4.85
1820	222	4	-2.97	-2.68
1920	226	5	-3.47	-3.59
2020	232	6	-3.69	-4.73
2120	225	6	-4.24	-4.24
2220	323	6	4.79	-3.61
2320	347	5	4.87	-1.12
0020	334	5	4.49	-2.19
0120	354	4	3.98	-0.42
0220	1	5	5	0.08
0320	1	4	4	0.07
0420	358	4	3.99	-0.14
0520	8	4	3.96	0.56
0620	0	4	4	0
0720	4	3	2.99	0.21
0820	7	4	3.97	0.49
0920	61	3	1.45	2.62
1020	83	4	0.49	3.97

Table 7.2.1.6 Current measurement records at station No.6 Rayong Province (11-12 May 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
1300	92	9	-0.32	8.99
1400	97	10	-1.22	9.93
1500	97	8	-0.98	7.94
1600	71	9	2.93	8.51
1700	84	9	0.95	8.96
1800	1	8	8.00	0.14
1900	344	6	5.77	-1.66
2000	14	6	5.82	1.45
2100	330	6	5.20	-3.00
2200	316	6	4.31	-4.17
2300	305	6	3.44	-4.91
0000	60	4	2.00	3.46
0100	104	6	-1.45	5.82
0200	119	8	-3.88	7.00
0300	116	9	-3.94	8.09
0400	90	8	0.00	8.00
0500	101	12	-2.29	11.78
0600	111	9	-3.22	8.41
0700	94	7	-0.49	6.99
0800	119	6	-2.91	5.25
0900	133	4	-2.73	2.92
1000	106	4	-1.10	3.84
1100	158	4	-3.71	1.50
1200	181	5	-5.00	-0.09

Table 7.2.1.7 Current measurement records at station No.6 Rayong Province (15-16 June 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
1200	2	11	10.99	0.39
1300	334	15	13.48	-6.57
1400	265	18	-1.57	-17.93
1500	320	16	12.26	-10.29
1600	288	14	4.33	-13.31
1700	293	14	5.47	-12.89
1800	313	13	8.87	-9.5
1900	303	12	6.54	-10.07
2000	315	11	7.78	-7.78
2100	236	9	-5.03	-7.46
2200	182	11	-10.99	-0.38
2300	126	11	-6.47	8.89
0000	19	11	10.41	3.59
0100	255	12	-3.11	-11.59
0200	330	11	9.53	-5.5
0300	120	12	-6	10.39
0400	348	12	11.74	-2.49
0500	106	14	-3.86	13.45
0600	112	14	-5.25	12.98
0700	126	16	-9.41	12.94
0800	120	15	-7.5	12.99
0900	61	18	8.73	15.75
1000	94	15	-1.05	14.97
1100	144	13	-10.52	7.64

Table 7.2.1.8 Current measurement records at station No.1
Petchaburi Province (2-3 February 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
1100	212	15	-12.72	-7.95
1200	257	14	-3.15	-13.64
1300	340	14	13.16	-4.79
1400	184	15	-14.97	-1.05
1500	331	13	11.38	-6.31
1600	338	15	13.91	-5.63
1700	161	17	-16.08	5.54
1800	180	18	-18	0
1900	157	19	-17.49	7.43
2000	191	21	-20.62	-4.01
2100	174	18	-17.91	1.89
2200	130	19	-12.22	14.55
2300	53	20	12.04	15.98
0000	21	31	28.95	11.09
0100	23	34	31.31	13.29
0200	12	32	31.29	6.65
0300	8	30	29.7	4.17
0400	14	24	23.28	5.81
0500	7	17	16.88	2.07
0600	358	11	10.98	-0.38
0700	210	16	-13.85	-8
0800	168	18	-17.6	3.74
0900	165	23	-22.22	5.96
1000	206	22	-19.78	-9.64

Table 7.2.1.9 Current measurement records at station No.1
Petchaburi Province (24-25 May 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
0900	312	14	9.37	-10.4
1000	291	16	-12.43	-10.06
1100	195	18	-17.39	-4.66
1200	143	19	-15.18	11.44
1300	156	20	-18.28	8.14
1400	248	22	-8.25	-20.39
1500	174	23	-22.89	2.41
1600	95	25	-2.17	24.9
1700	14	31	30.07	7.5
1800	8	29	28.71	4.03
1900	28	26	22.96	12.19
2000	47	24	16.37	17.54
2100	9	17	16.79	2.65
2200	353	14	13.9	-1.71
2300	83	12	1.46	11.92
0000	219	12	-9.32	-7.55
0100	189	15	-14.82	-2.34
0200	205	16	-14.49	-6.77
0300	167	18	-17.53	4.05
0400	174	17	-16.91	1.78
0500	170	17	-16.74	2.96
0600	216	16	-12.94	-9.41
0700	205	17	-15.4	-7.19
0800	108	16	-4.94	15.22

Table 7.2.1.10 Current measurement records at station No.6 Petchaburi Province (25-26 May 1988)

Time	Direction	Speed (cm/sec.)	Component N	Component E
1204	327	11	9.23	-5.99
1304	174	13	-12.94	1.36
1404	303	15	8.17	-12.58
1504	112	17	-6.37	15.76
1604	341	15	14.19	-4.89
1704	14	16	15.52	3.87
1804	2	17	16.98	0.59
1904	52	20	12.32	15.76
2004	340	23	21.62	-7.87
2104	354	20	19.9	-2.1
2204	12	15	14.67	3.12
2304	23	11	10.13	4.3
0004	19	8	7.57	2.61
0104	236	10	-5.59	-8.29
0204	202	14	-12.98	-5.25
0304	201	18	-16.81	-6.44
0404	203	16	-14.74	-6.26
0504	191	16	-15.71	-3.06
0604	189	14	-13.83	-2.18
0704	241	13	-6.31	-11.37
0804	227	12	-8.18	-8.77
0904	226	11	-7.64	-7.91
1004	83	13	1.58	12.91
1104	293	11	4.3	-10.13

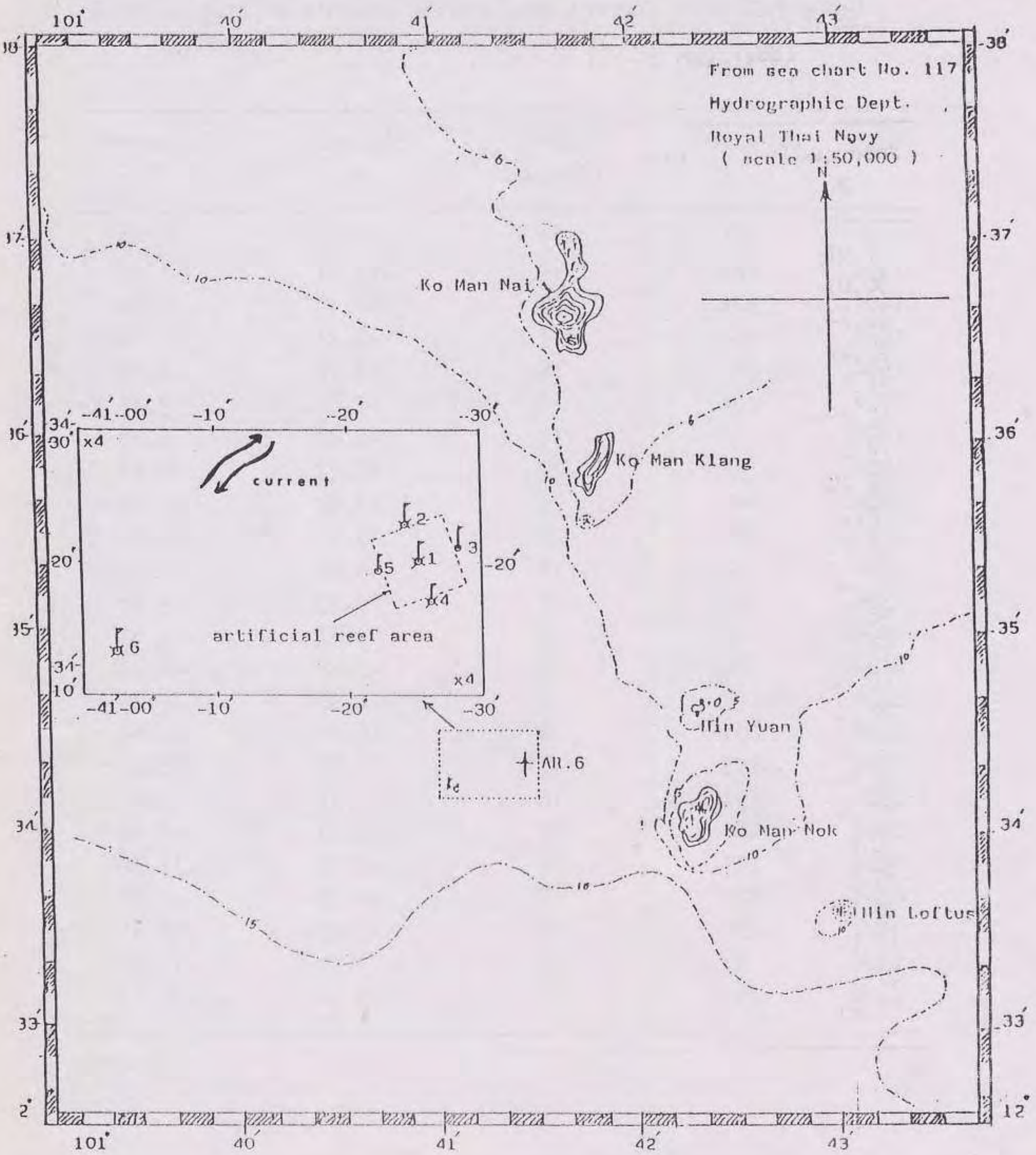


Fig. 7.2.1.1 Survey station and area at Rayong artificial reef No.6

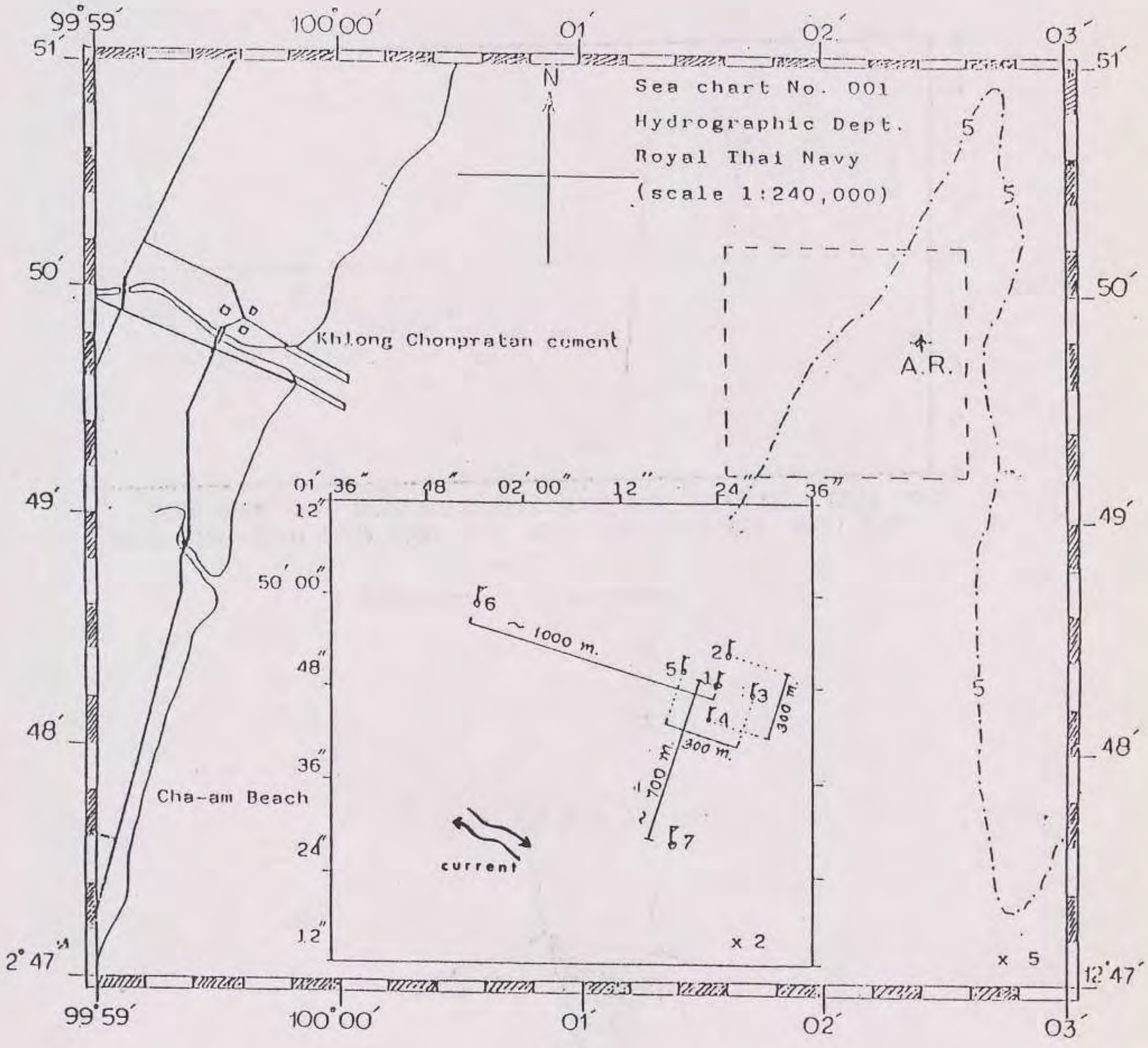
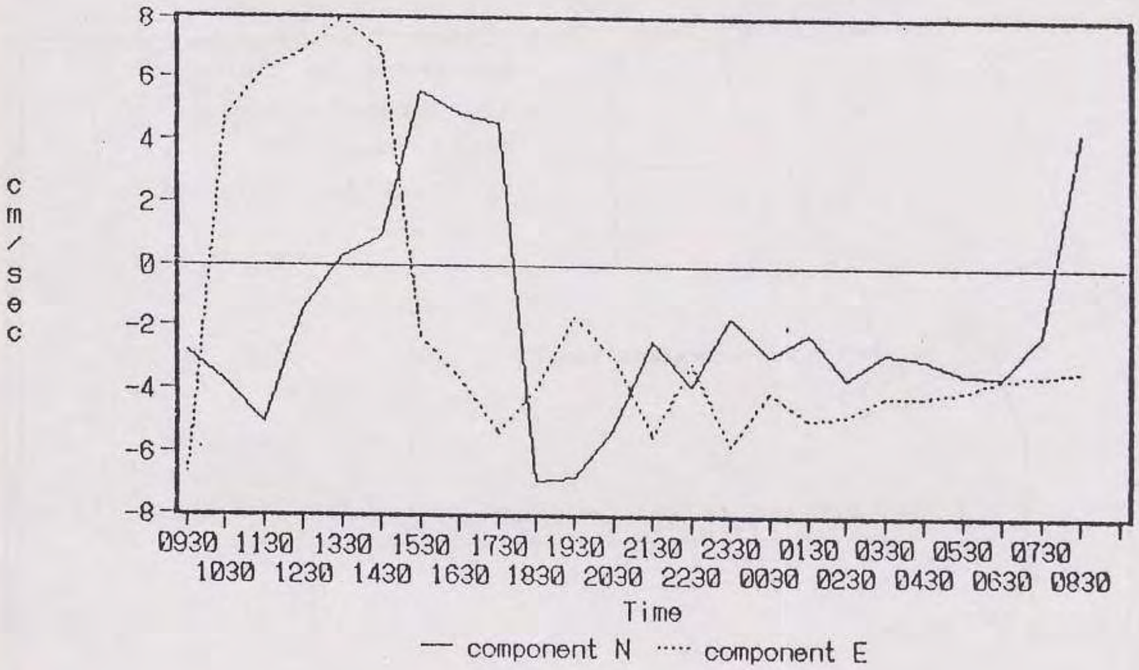


Fig. 7.2.1.2 Survey station and area at Petchaburi artificial reef No.1 (Cha-am)



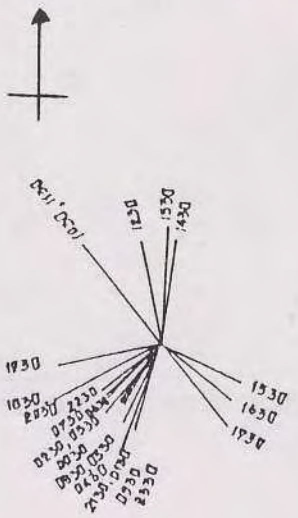


Fig. 7.2.1.3 Current direction histograms and components of the 2 m. layer over the bottom at station No. 1, Rayong (26-27 January 1988)

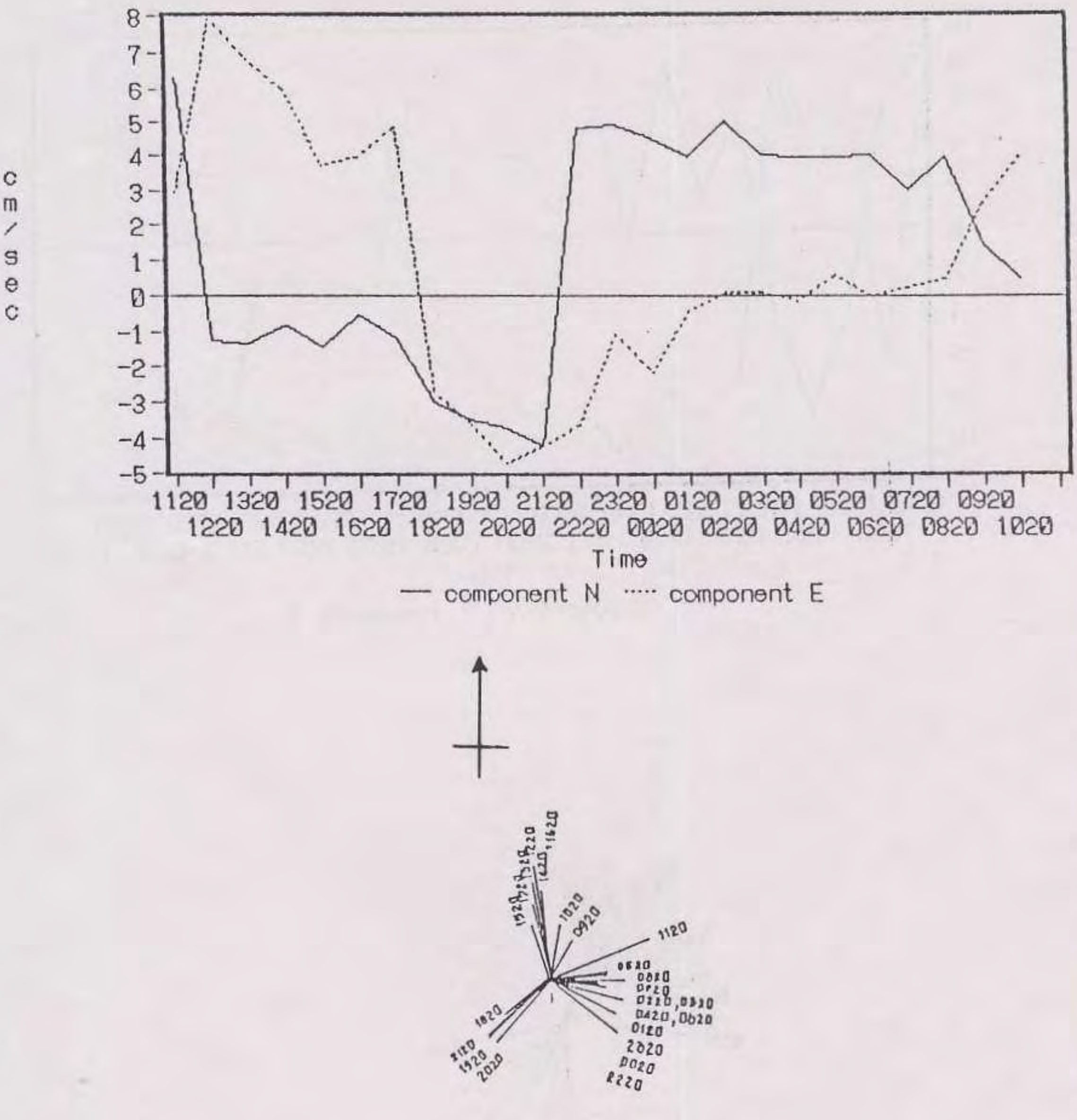
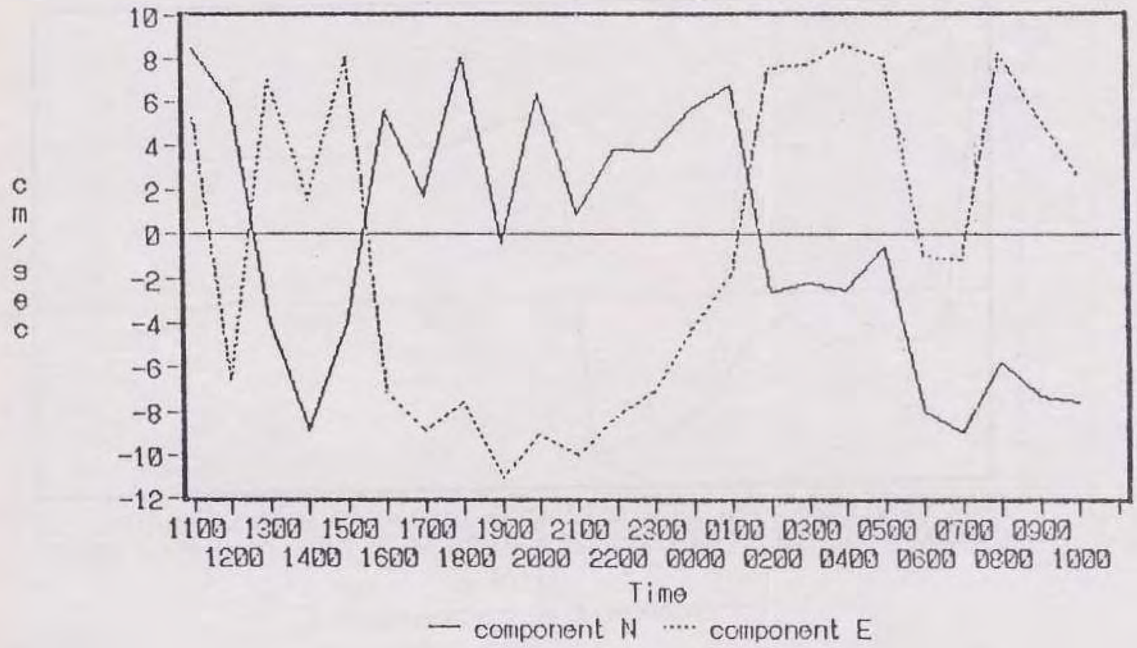


Fig. 7.2.1.4 Current direction histograms and components of the 2 m. layer over the bottom at station No.6, Rayong (27-28 January 1988)



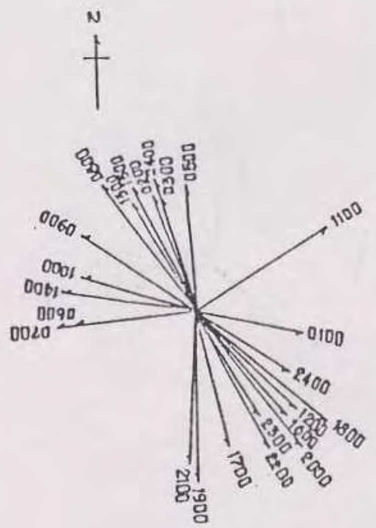
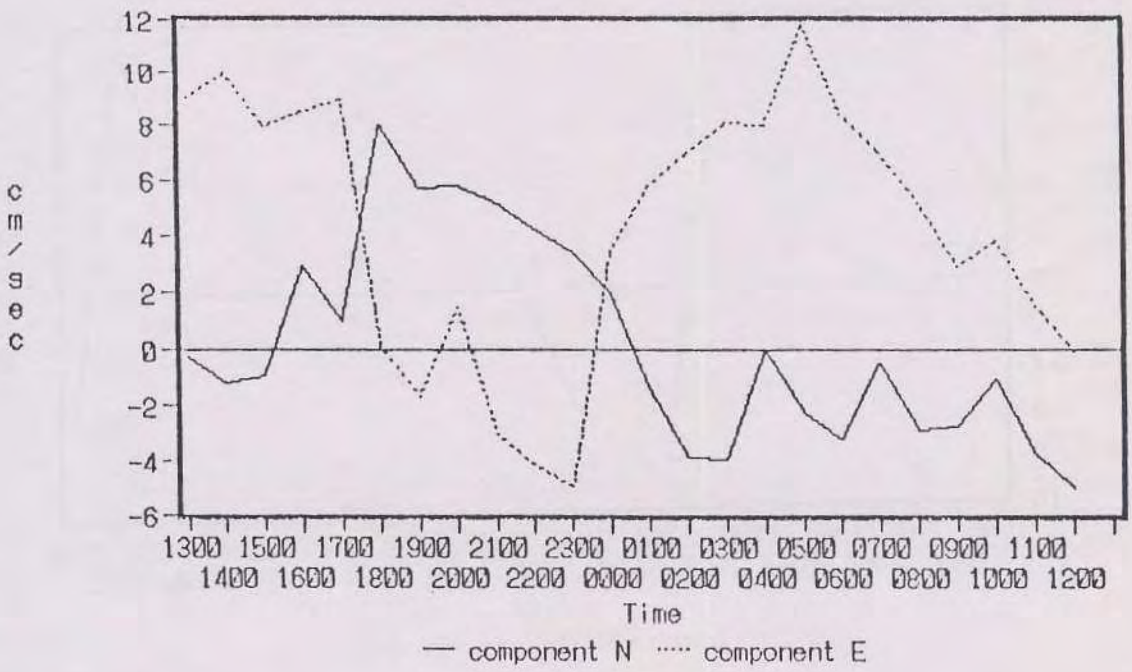


Fig. 7.2.1.5 Current direction histograms and components of the 2 m. layer over the bottom at station No.1, Rayong (10-11 May 1988)



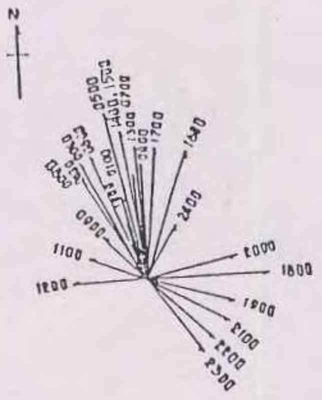
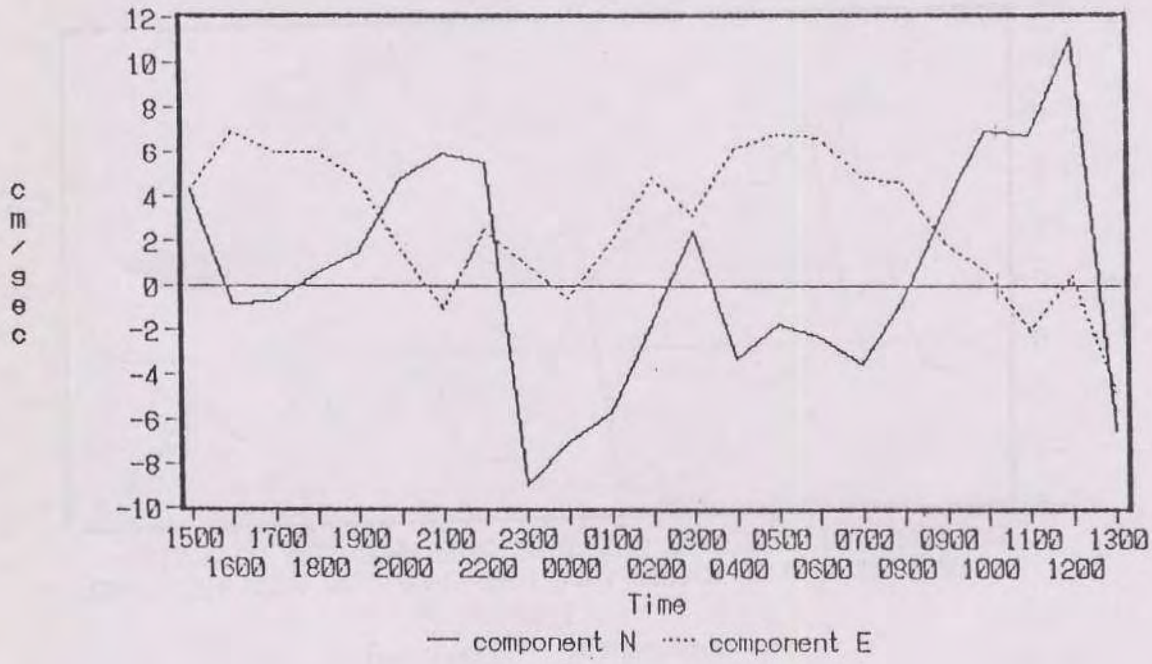


Fig. 7.2.1.6 Current direction histograms and components of the 2 m. layer over the bottom at station No.6, Rayong (11-12 May 1988)



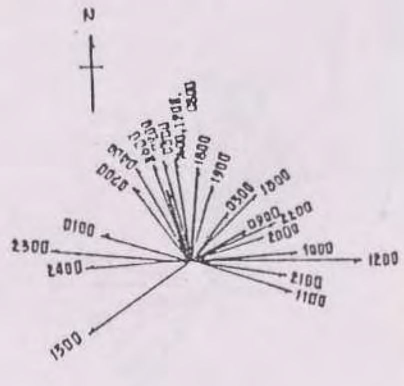
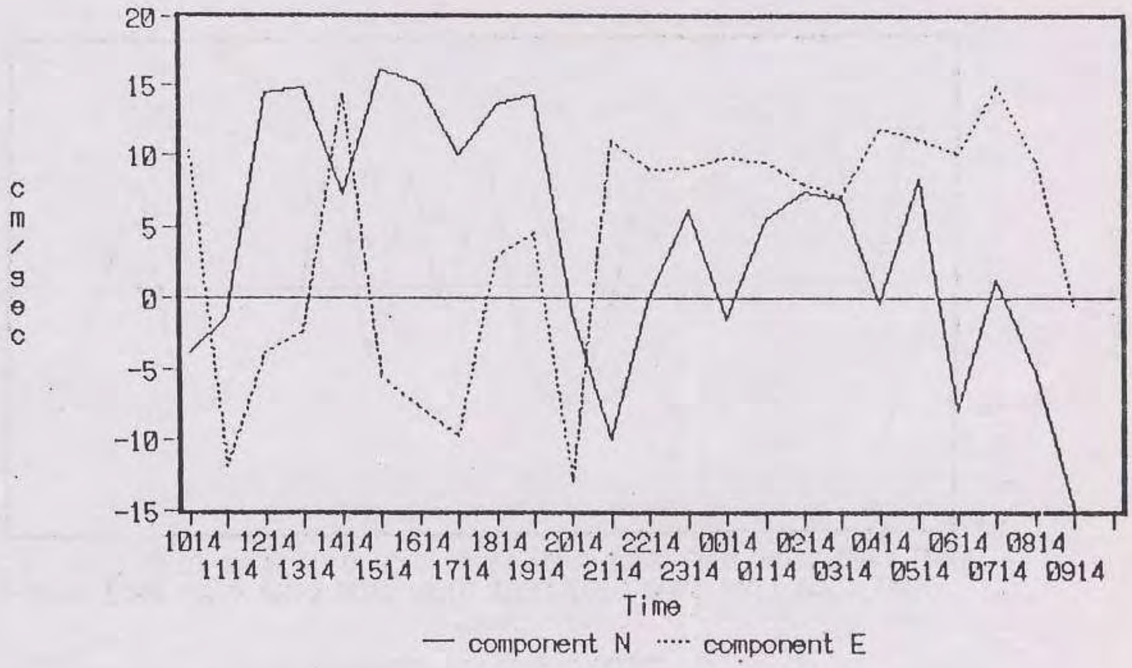


Fig. 7.2.1.7 Current direction histograms and components of the 2 m. layer over the bottom at station No. 1, Rayong (12-13 May 1988)



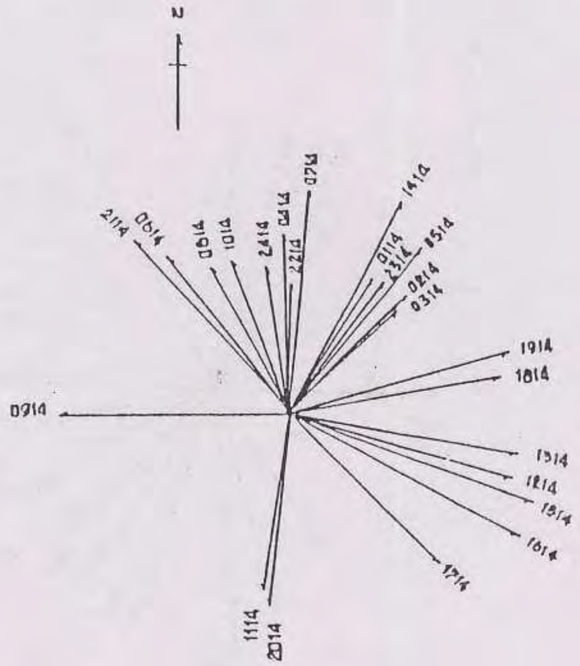


Fig. 7.2.1.8 Current direction histograms and components of the 2 m. layer over the bottom at station No.1, Rayong (14-15 June 1988)

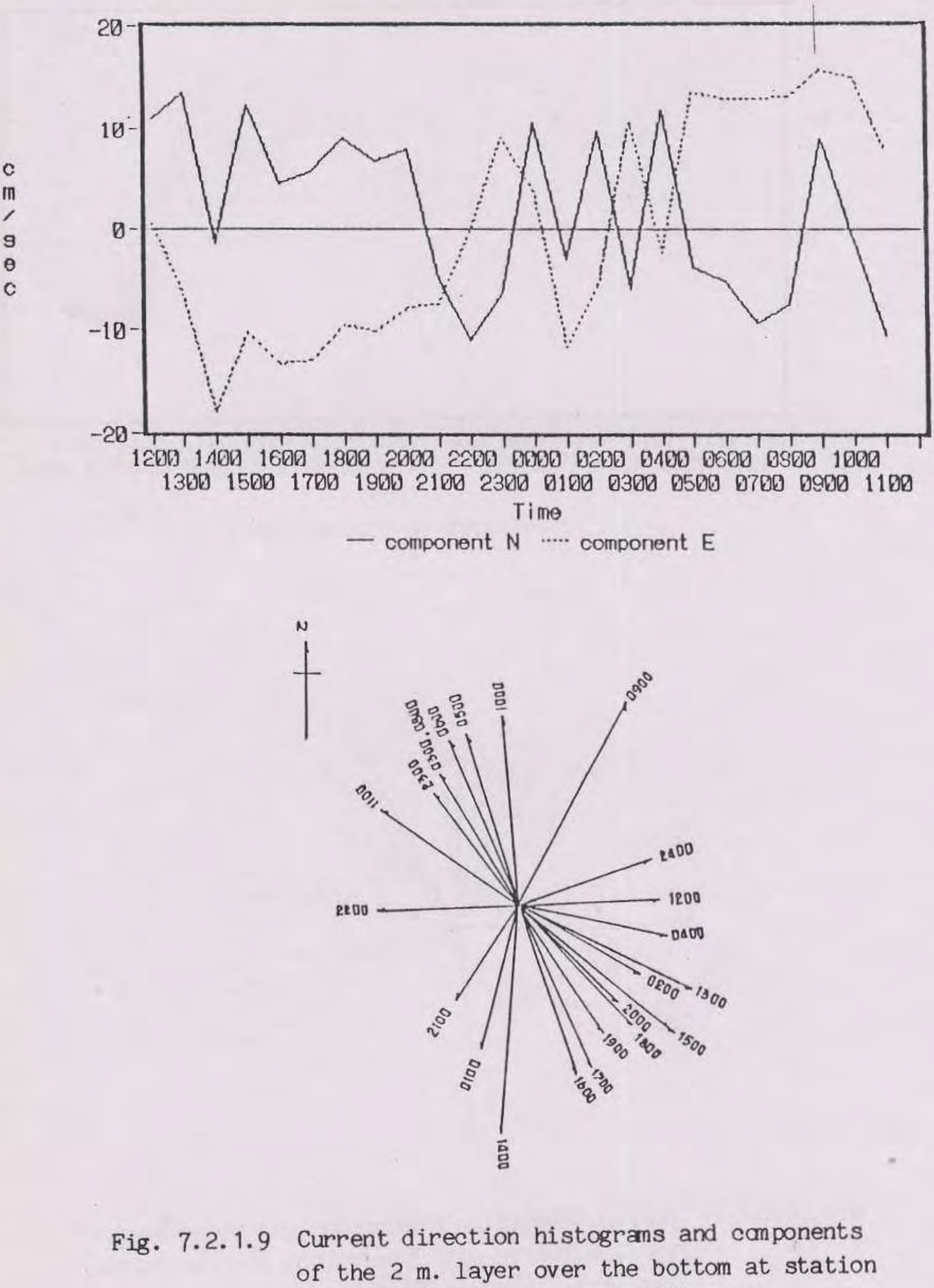


Fig. 7.2.1.9 Current direction histograms and components of the 2 m. layer over the bottom at station No.6, Rayong (15-16 June 1988)

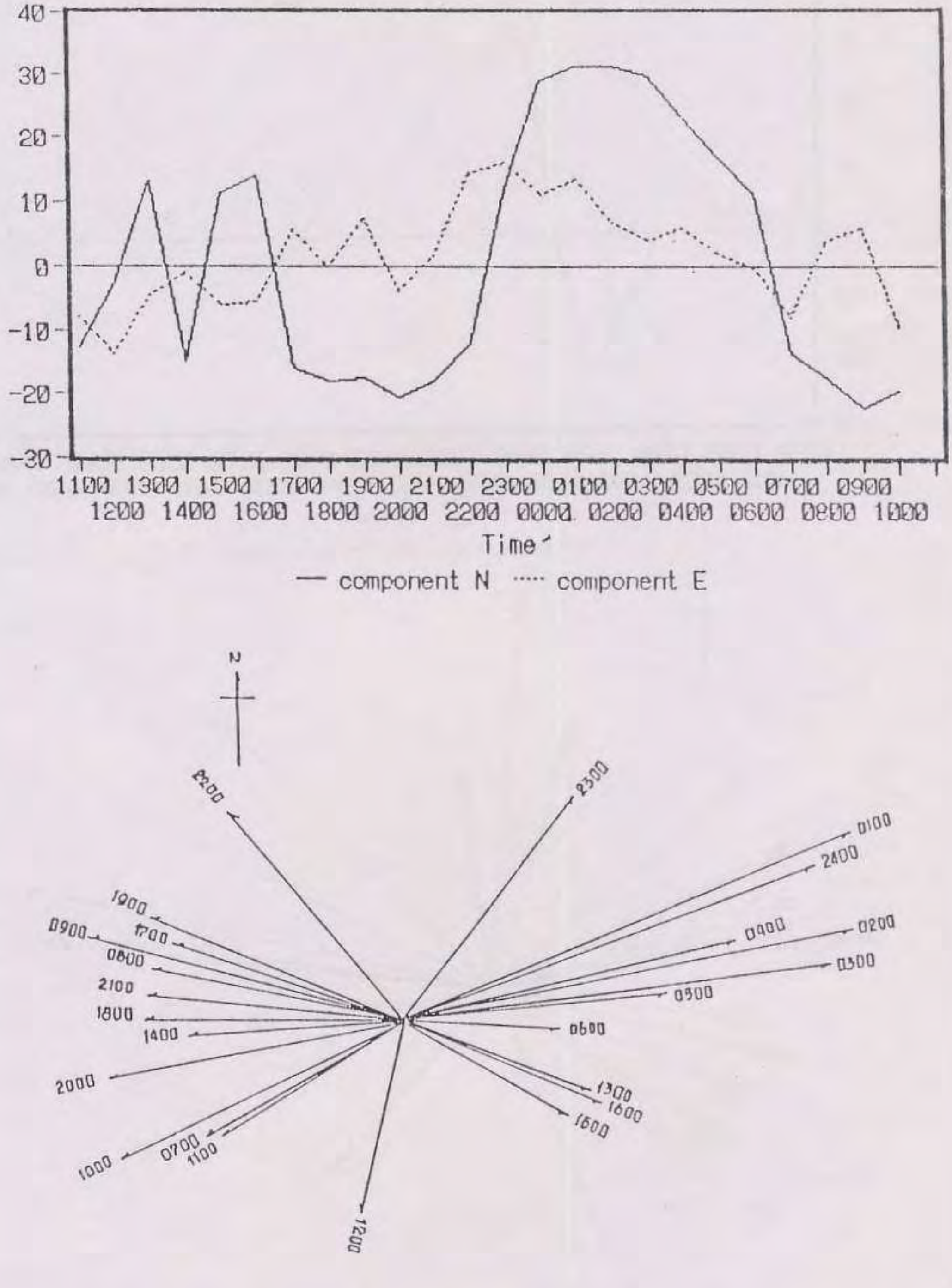


Fig. 7.2.1.10 Current direction histograms and components of the 2 m. layer over the bottom at station No. 1, Petchaburi (2-3 February)

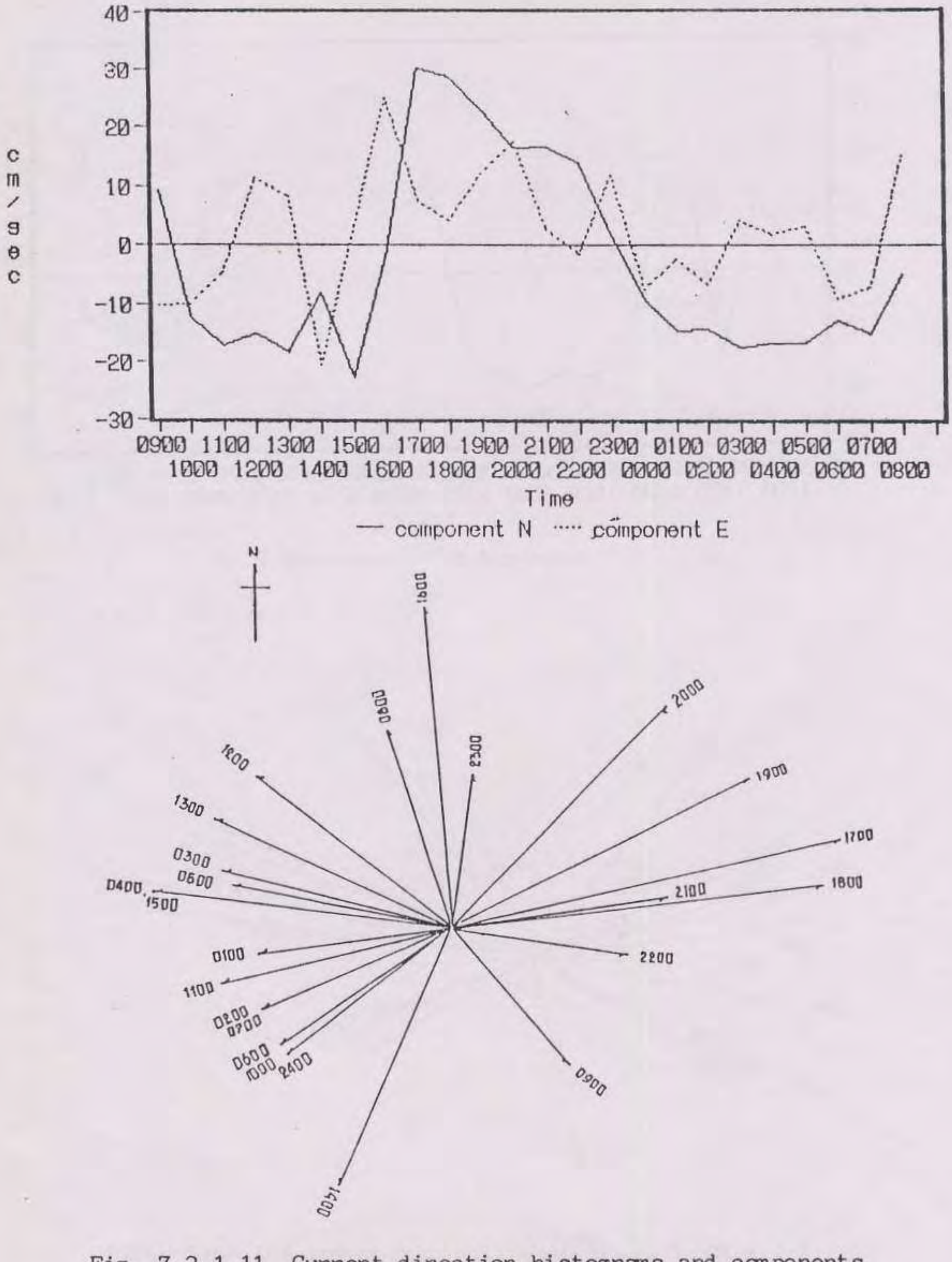


Fig. 7.2.1.11 Current direction histograms and components of the 2 m. layer over the bottom at station No. 1, Petchaburi (24-25 May 1988)

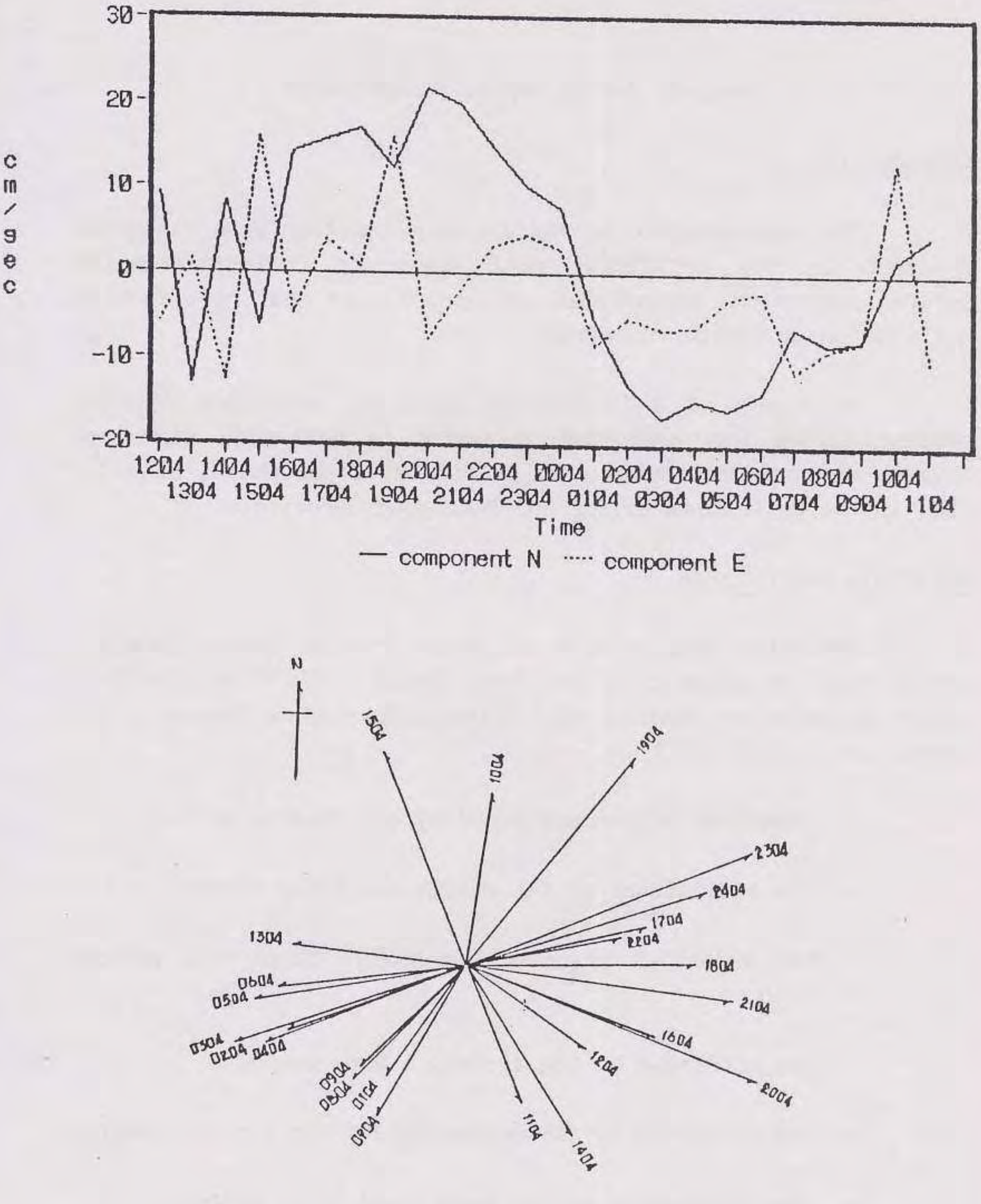


Fig. 7.2.1.12 Current direction histograms and components of the 2 m. layer over the bottom at station No.6, Petchaburi (25-26 May 1988)

7.2.2 Chemical Survey (by S. Ruangsivakul)

Introduction

The oceanographic survey was done together with fisheries research in the artificial reef areas to collect detailed information on the conservation of marine life and the effective utilization of marine resources.

As a part of a fundamental study of water quality, the present survey was conducted in order to determine dissolved oxygen, and nutrient salts such as silicate, phosphate, nitrate, etc. in the waters off Rayong and Petchaburi Provinces.

Materials and Methods

Sea water samples were collected from two layers (surface and bottom) by means of a Van Dorn bottle. For the nutrients analysis the water samples were filtered through a Whatman glass microfiber filter (GF/A).

- dissolved oxygen was found by the Winkler method
- the silicate-Si by the Mullin and Riley method
- the ammonia-N by several methods, taken from various authors
- the nitrate-N by the Ilosvay & Dung method
- the nitrite-N by the Bendschneider and Robinson method
- the phosphate-P by the Murphy and Riley method
- the chemical oxygen demand (COD) of mud by the reduction of permanganate method

- the sediments were collected with an Exman-Berge bottom sampler. To determine the grain size composition, a sample sediment of about 50 to 100 g (dry weight) was sieved through strainers of different mesh sizes, separating the sample into four parts, viz., granules (shell fragments) sand, silt and clay.

Results

At Rayong, water samples were collected from three cruises:

- 1st cruise on 29 January 1988
- 2nd cruise on 13 May 1988
- 3rd cruise on 16 June 1988

The results are shown in Tables 7.2.2.1, 7.2.2.2, 7.2.2.3, and Figs. 7.2.2.1, 7.2.2.2, 7.2.2.3, 7.2.2.4.

a. Dissolved oxygen ranged between

5.09 - 5.62 ml/L (1st)
3.22 - 5.19 ml/L (2nd)
3.75 - 4.43 ml/L (3rd)

b. Silicate ranged between

10.92 - 18.47 ug-at/L (1st)
14.77 - 39.77 ug-at/L (2nd)
13.82 - 18.83 ug-at/L (3rd)

c. Ammonia ranged between

0 - 56.44 ug-at/L (1st)
ND (2nd)
6.5 - 21.0 ug-at/L (3rd)

d. Nitrate ranged between

2.15 - 3.10 ug-at/L (1st)
0.4 - 0.85 ug/at/L (2nd)
ND (3rd)

e. Nitrite ranged between

0.19 - 0.58 ug-at/L (1st)
0.69 - 2.52 ug-at/L (2nd)
0 - 3.08 ug-at/L (3rd)

f. Phosphate ranged between

0.49 - 2.46 ug-at/L (1st)
0.89 - 1.79 ug-at/L (2nd)
0 - 16.09 ug-at/L (3rd)

g. Chemical oxygen demand ranged between

0.38 - 2.34 mg/g (1st)
1.66 - 4.16 mg/g (2nd)
0.67 - 2.96 mg/g (3rd)

h. Grain size

Mainly medium sand

At Petchaburi, water samples were collected from two cruises:

- 1st cruise on 4 February 1988
- 2nd cruise on 26 May 1988

The results are shown in Tables 7.2.2.4, 7.2.2.5, 7.2.2.6, and Figs. 7.2.2.5, 7.2.2.6, 7.2.2.7.

a. Dissolved oxygen ranged between

4.98 - 6.05 ml/L (1st)
4.10 - 5.72 ml/L (2nd)

b. Silicate ranged between

13.58 - 18.52 ug-at/L (1st)
1.60 - 5.45 ug-at/L (2nd)

c. Ammonia ranged between

0 - 12.71 ug-at/L (1st)
0 - 25.38 ug-at/L (2nd)

d. Nitrate ranged between

ND (1st)
ND (2nd)

e. Nitrite ranged between

0 - 0.84 ug-at/L (1st)
0 - 2.22 ug-at/L (2nd)

f. Phosphate ranged between

2.38 - 4.28 ug-at/L (1st)
0 - 1.32 ug-at/L (2nd)

g. Chemical oxygen demand ranged between

3.46 - 5.43 mg/g (1st)
2.19 - 3.92 mg/g (2nd)

h. Grain size

Mainly coarse sand

Summary

In this section, the findings of the survey can be summed up as follows:

At Rayong

1. In the first survey the water temperature, salinity and dissolved oxygen showed no difference between inside and outside the reefs, but in the second survey the salinity was lower than the first and third surveys, maybe because of the low tide (Tide table at Chong Samet, May 1988).

2. The highest amount of nutrient salts in the water was found to be in the bottom layer both inside and outside the reefs. This could be a result of the marine animal community in the reefs and/or a result of freshwater run-off.

3. The bottom sediment consisted mainly of medium sand both inside and outside the reefs.

At Petchaburi

4. The water temperature and salinity were generally no different inside and outside the reefs, but the first survey water temperature was lower than the second survey, maybe because of the winter season. The dissolved oxygen content inside the reefs was higher than outside the reefs.

5. The nutrient salts inside and outside the reefs were no different.

6. The bottom sediment consisted mainly of coarse sand both inside and outside the reefs.

Note : ND = below limit of detection

Table 7.2.2.1 Results off Rayong

St. No.	Depth	Temperature (°C)				Salinity (‰)				DO (ml/L)			
		1st	2nd	3rd	average	1st	2nd	3rd	average	1st	2nd	3rd	average
1	S	28.17	29.70	29.50	29.12	31.51	28.77	31.57	30.62	5.43	5.19	4.38	5.00
	B	27.97	30.29	29.50	29.25	31.58	30.59	31.64	31.27	5.30	3.22	4.43	4.32
2	S	28.21	29.75	29.50	29.15	31.51	28.50	31.62	30.54	5.53	4.60	4.14	4.75
	B	28.04	30.23	29.50	29.25	31.54	30.44	-	30.99	5.62	4.74	4.11	4.82
4	S	28.21	29.80	29.47	29.16	31.51	28.61	31.49	30.54	5.48	4.45	4.33	4.75
	B	27.97	30.28	29.60	29.28	31.57	30.60	31.71	31.29	5.09	3.65	3.75	4.16
6	S	28.45	29.87	29.50	29.27	31.49	29.06	31.60	30.72	5.36	4.54	4.36	4.75
	B	28.05	30.25	29.60	29.30	31.55	30.52	31.73	31.27	5.34	3.80	3.82	4.32

Note : S - surface
B - bottom

Table 7.2.2.2 Concentration of Nutrient Salts off Rayong

St. No.	Depth	Silicate (ug-at/L)				Phosphate (ug-at/L)				Nitrite (ug-at/L)			
		1st	2nd	3rd	average	1st	2nd	3rd	average	1st	2nd	3rd	average
1	S	13.11	14.77	13.82	13.90	1.48	1.34	ND	0.94	0.58	1.17	0.51	0.75
	B	18.47	16.60	15.86	16.97	2.46	0.89	16.09	6.48	0.58	2.28	2.56	1.81
2	S	11.19	18.59	18.09	15.95	1.48	0.89	0.73	1.03	0.38	1.14	2.05	1.19
	B	16.58	39.77	18.64	25.00	1.97	0.89	ND	0.95	0.19	1.61	3.08	1.63
4	S	10.92	18.27	18.83	16.00	1.97	0.89	ND	0.95	0.19	0.94	ND	0.56
	B	15.89	19.36	18.83	18.02	0.98	1.79	ND	0.92	0.58	2.52	ND	1.03
6	S	11.62	21.23	18.09	16.98	0.49	1.34	ND	0.61	0.58	1.84	ND	0.81
	B	15.89	18.49	14.01	16.13	1.48	0.89	ND	0.79	0.58	0.69	MD	0.42

St. No.	Depth	Nitrate (ug-at/L)				Ammonia (ug-at/L)			
		1st	2nd	3rd	average	1st	2nd	3rd	average
1	S	2.15	0.45	ND	0.86	11.69	ND	9.00	6.89
	B	2.30	0.40	ND	0.90	10.17	ND	11.50	7.20
2	S	3.10	0.75	ND	1.28	16.78	ND	9.50	8.76
	B	2.50	0.85	ND	1.12	ND	ND	21.00	7.00
4	S	2.30	0.75	ND	1.02	ND	ND	10.50	3.50
	B	2.30	0.58	ND	0.96	7.12	ND	7.50	4.87
6	S	2.60	0.40	ND	1.00	56.44	ND	6.50	20.9
	B	2.50	0.45	ND	0.98	10.68	ND	10.0	6.89

Note : S - surface
B - bottom

Table 7.2.2.3 Statistical Analysis of Sediment

St. No.	Rayong	Medium grain size (mm)	Grade of particle size	Sorting Coef. (s)	Degree of sorting	COD mg/g
1	1st	0.51	coarse sand	1.670	well-sorted	0.38
	2nd	0.43	medium sand	2.710	moderately	1.66
	3rd	0.66	coarse sand	1.960	well-sorted	0.67
	average	0.53	coarse sand			0.90
2	1st	0.38	medium sand	3.960	moderately	1.80
	2nd	0.42	medium sand	2.898	moderately	4.16
	3rd	0.86	coarse sand	2.360	well-sorted	2.00
	average	0.55	coarse sand			2.65
3	1st	0.31	medium sand	2.370	well-sorted	0.95
	2nd	0.68	coarse sand	2.369	well-sorted	0.69
	3rd	0.22	medium sand	3.740	moderately	5.35
	average	0.40	medium sand			2.33
4	1st	0.08	fine sand	2.230	well-sorted	2.34
	2nd	0.52	coarse sand	2.250	well-sorted	3.51
	3rd	0.09	fine sand	1.950	well-sorted	2.16
	average	0.23	fine sand			2.67
5	1st	0.45	medium sand	2.260	well-sorted	1.35
	2nd	0.27	medium sand	2.638	moderately	3.46
	3rd	0.32	medium sand	2.480	well-sorted	2.66
	average	0.34	medium sand			2.49
6	1st	0.90	medium sand	4.670	poorly-sorted	1.96
	2nd	0.38	medium sand	3.162	moderately	1.79
	3rd	0.64	coarse sand	4.400	poorly-sorted	2.96
	average	0.64	coarse sand			2.23

Table 7.2.2.4 Results off Petchaburi

St. No.	Depth	Temperature(°C)		average	Salinity (‰)		average	DO (ml/L)		average
		1st	2nd		1st	2nd		1st	2nd	
1	S	28.39	31.70	30.04	30.69	30.87	30.78	6.05	5.12	5.58
	B	28.19	31.63	29.91	30.67	31.02	30.84	5.08	4.43	4.75
2	S		31.80			30.86			4.82	
	B		31.65			31.03			4.49	
3	S	28.31	31.59	29.95	30.70	30.96	30.83	5.36	5.72	5.54
	B	28.02	31.59	29.81	30.70	31.00	30.85	4.98	4.82	4.90
4	S		31.93			30.85			4.61	
	B		31.69			31.01			4.76	
6	S	28.54	31.70	30.12	30.63	30.81	30.72	5.36	4.79	5.07
	B	28.08	31.74	29.91	30.61	30.97	30.97	5.71	4.10	4.90
7	S	28.41			30.65			5.48		
	B	28.30			30.65			5.44		

Note : S - surface
B - bottom

Table 7.2.2.5 Concentration of Nutrient Salts off Petchaburi

St. No.	Depth	Silicate (ug-at/L)			Phosphate (ug-at/L)			Nitrite (ug-at/L)		
		1st	2nd	average	1st	2nd	average	1st	2nd	average
1	S	15.33	3.95	9.64	3.33	ND	1.66	ND	0.44	0.22
	B	18.52	3.95	11.23	4.28	1.32	2.80	0.21	0.44	0.32
2	S		2.73			1.32			0.44	
	B		5.45			ND			2.22	
3	S	13.58	5.07	9.32	2.86	ND	1.43	0.84	ND	0.42
	B	14.40	3.76	9.08	2.38	0.44	1.41	ND	0.44	0.22
4	S		1.60			0.44			ND	
	B		4.98			0.44			ND	
6	S	17.28	3.48	10.38	3.33	0.44	1.88	0.63	ND	0.31
	B	16.67	2.82	9.74	4.28	0.44	2.36	ND	ND	ND
7	S	13.99			3.33			ND		
	B	16.98			2.86			0.84		

St. No.	Depth	Nitrate (ug-at/L)			Ammonia (ug-at/L)		
		1st	2nd	average	1st	2nd	average
1	S	ND	ND	ND	2.03	11.54	6.78
	B	ND	ND	ND	1.02	ND	0.51
2	S		ND			18.46	
	B		ND			16.15	
3	S	ND	ND	ND	ND	18.46	9.23
	B	ND	ND	ND	12.71	7.85	10.28
4	S		ND			ND	
	B		ND			25.38	
6	S	ND	ND	ND	4.07	0.92	2.49
	B	ND	ND	ND	ND	ND	ND
7	S	ND			1.53		
	B	ND			ND		

Note : S - surface
B - bottom

Table 7.2.2.6 Statistical Analysis of Sediment

St. No.	Petchaburi	Medium grain size (mm)	Grade of particle size	Sorting Coef. (s)	Degree of sorting	COD mg/g
1	1st	0.48	medium sand	3.114	moderately	3.55
	2nd	1.38	very coarse sand	2.210	moderately	2.41
	average	0.93	coarse sand			2.98
2	2nd	1.65	very coarse sand	2.230	well-sorted	2.19
3	1st	0.39	medium sand	3.179	moderately	5.43
	2nd	1.07	very coarse sand	2.930	moderately	3.92
	average	0.73	coarse sand			4.67
4	2nd	1.05	very coarse sand	2.730	moderately	3.42
5	2nd	0.50	medium sand	2.385	well-sorted	-
6	1st	0.36	medium sand	3.115	moderately	3.46
	2nd	0.62	coarse sand	2.906	moderately	3.16
	average	0.49	medium sand			3.31
7	1st	0.39	medium sand	4.400	poorly-sorted	5.08

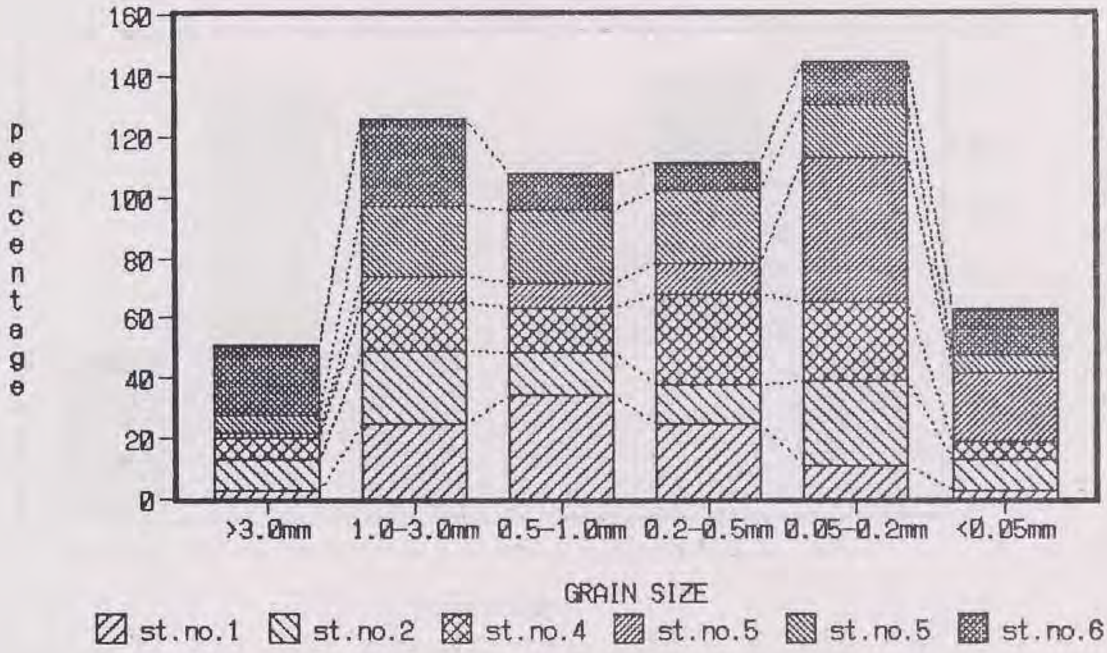


Fig. 7.2.2.1 Grain Size off Rayong (I)

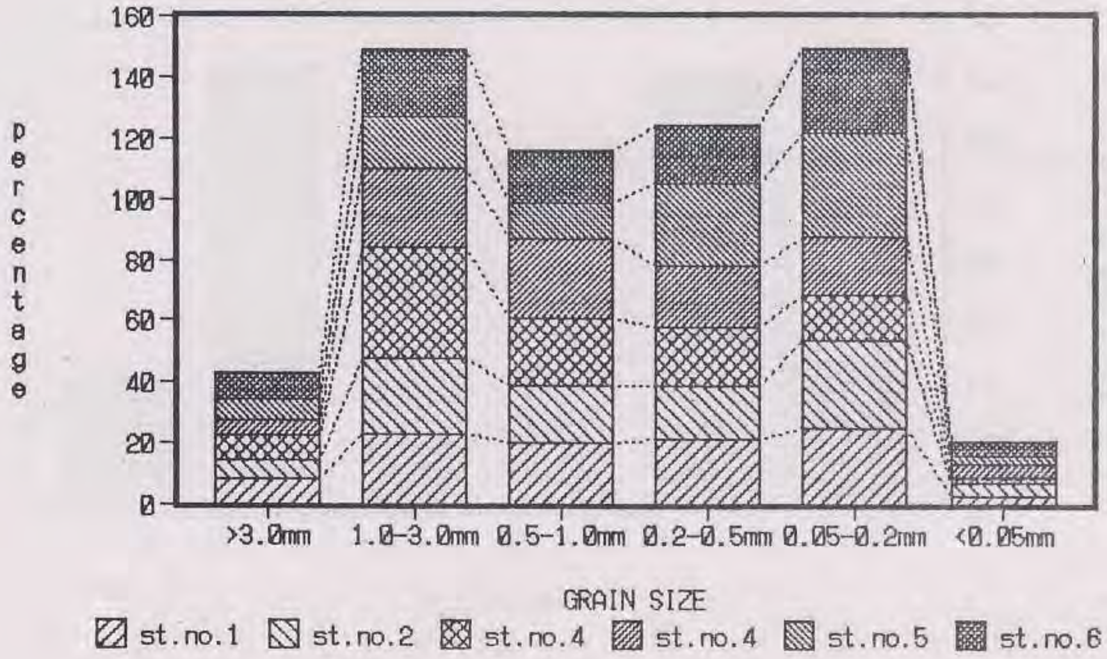


Fig. 7.2.2.2 Grain Size off Rayong (II)

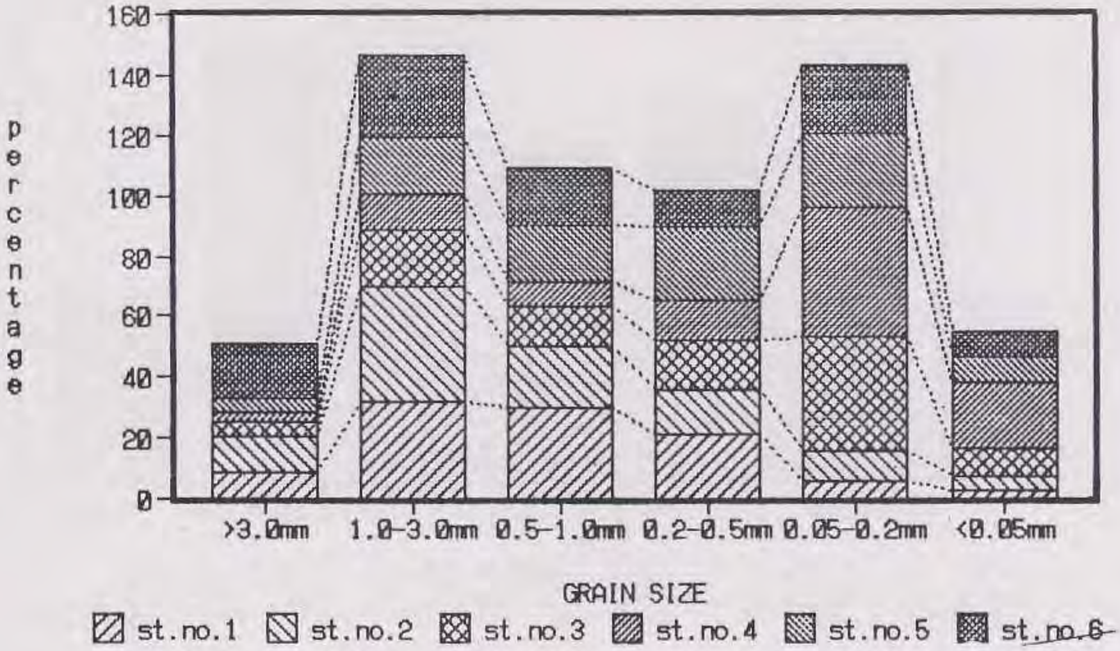


Fig. 7.2.2.3 Grain Size off Rayong (III)

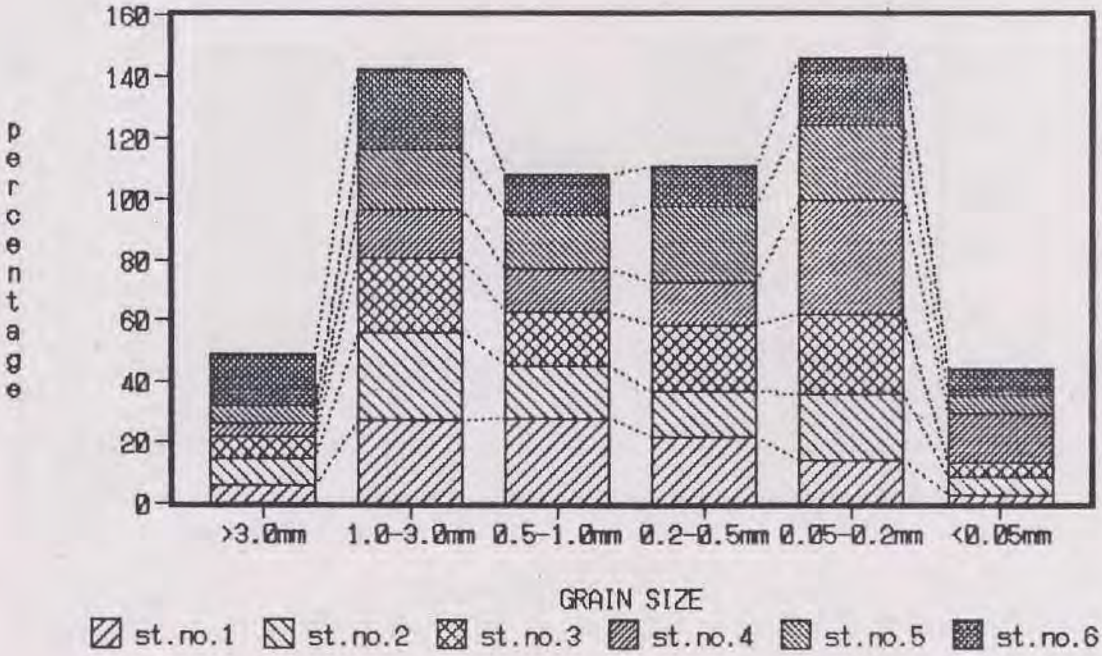


Fig. 7.2.2.4 Grain Size off Rayong (average)

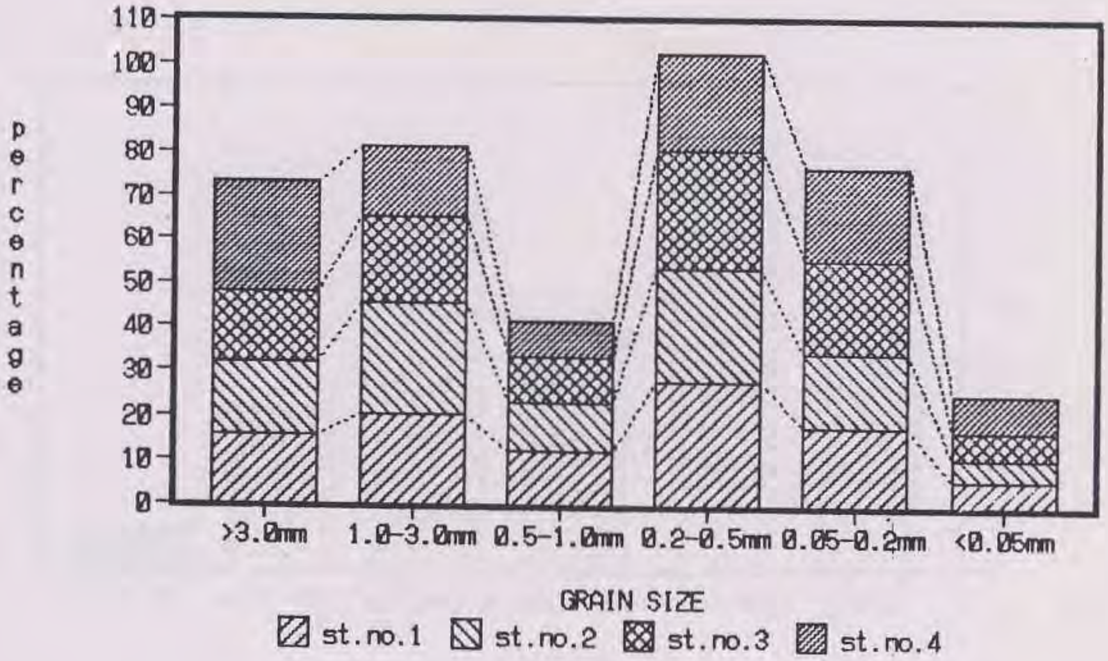


Fig. 7.2.2.5 Grain size off Petchaburi (I)

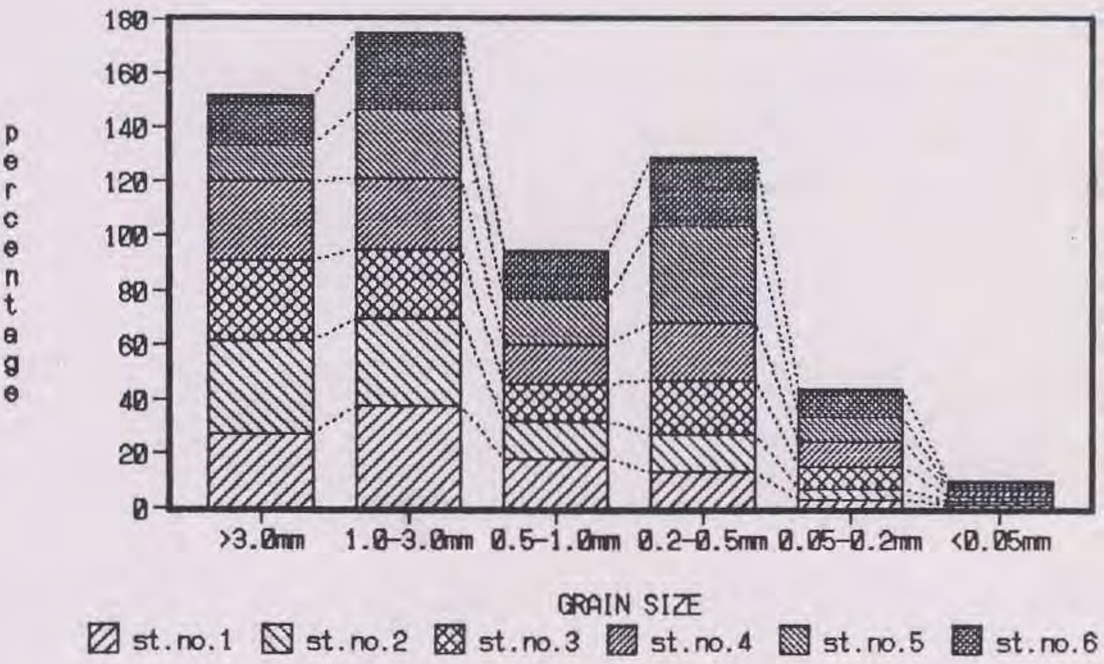


Fig. 7.2.2.6 Grain Size off Petchaburi (II)

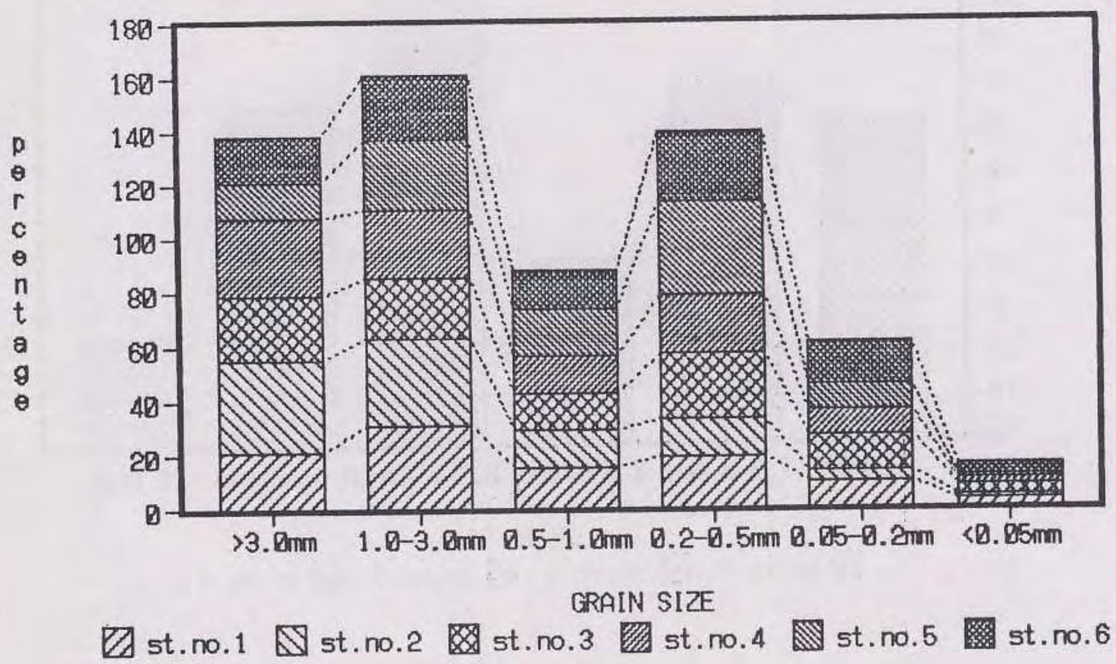


Fig. 7.2.2.7 Grain Size off Petchaburi (average)

7.3 Biological Research

7.3.1 Observation Survey (by A. Munprasit)

The purpose of this survey was to observe the conditions and situation of sessile organisms inside and around artificial reefs. The survey was divided into three areas: diving, underwater photography & video recordings and fishfinder observations.

Materials and Methods

The site was searched and its position confirmed by echo-sounder (Furuno FE-606). The underwater observations were carried out by Scuba diving, underwater video camera and underwater photographic camera. After the position of the reef had been confirmed, marker buoys were set on the sea surface to indicate the area of the site. The underwater activities were carried out taking into consideration the weather and sea conditions. Each dive was approximately 30-50 minutes in duration and there were 3-4 dives (depending upon the sea conditions) per trip. The underwater surveys were usually conducted between 10.00 and 15.00 hrs.

The underwater observations were carried out by three researchers; pictures were taken by underwater photographic camera, and video cassettes were recorded from the underwater video camera through a monitor on board. The reef structure and reef condition, including, fishes, flora and fauna were observed visually. In addition, sessile organisms and bottom sediment were collected in order to study the reef community as well as the sediment's grain size.

Results

Diving observations

1. Rayong artificial reef: The materials employed were used tires and concrete drain pipes. Both were tied together into a unit of 4 or 7 pieces with either iron wire 7 x ϕ 2 m.m., Polyethylene rope ϕ 4-6 m.m. or belt-type plastic rope. At this stage most of the units were broken down and lay over the sea-bed. Some of the pieces were scattered nearby the area and covered with sediment. However, some had stayed together in a small area of approximately 160 square meters. Most of the reef units tied together with the belt-type plastic rope were still in a good condition, while the ones connected with iron wire were completely broken. Some of the remaining iron wire was found on the reef (Fig. 7.3.1.1).

Petchaburi artificial reef: The materials employed were used tires. They were tied together into a unit of 4 pieces with iron wire ϕ 3-4 m.m.. By diving, a scattered pattern of the remaining material was found. The scattered materials (tires) lay over the sandy mud bottom and formed groups of 3-4 tires. Each group was separated by about 10 to 20 meters in distance, however, in the survey area of 300 square meters one small area (15 square meters approximately) had a concentration of approximately 100 tires in it. All of the reef units have completely broken up, no remaining tied up material was found. (Fig. 7.3.1.2)

2. The marine organisms found in and around the Rayong artificial reefs included many sessile animals, fauna and flora, such as, sponges, soft corals, sea fans, pearl shell (*Pinctada* sp.), oysters, polychaete groups, sea stars, Bryozoa and sea cucumbers.

Bryozoa groups and green mussels were found to be dominant organisms on the reef off Petchaburi. A small area of sea fans was observed in the survey area, all of them growing up from a sandy bottom with scattered stones. Bottom sediment was sandy and contained broken shell with little mud present.

3. Various fishes were observed in and around the Rayong artificial reef, most of them were demersal species. A school of Indian mackerel and banded crevalle were also observed on the surface. About 28 kinds of demersal fish were found as shown in the list on page 68.

A few fish were observed by divers in and around the artificial reef at Cha-Am, Petchaburi. They were both pelagic and demersal species as shown in the list on page 69.

Video recording

While the divers were carrying out underwater observations in and around the site, an underwater TV camera was carried along and the other researchers could see through the TV monitor on the vessel at the same time. The underwater visual observations were also recorded by video cassette through the TV monitor. Three cassettes were recorded at the Rayong artificial reef totalling 180 minutes, one 90 minutes cassette was recorded at the Petchaburi artificial reef. After finishing the field survey all the cassettes were reviewed and the interesting or important scenes were taken to produce a 30 minutes cassette.

Observations by Fishfinder

An echo-sounder survey was conducted after marker buoys had been set around the site area. The vessel sailed across the reef several times at low speed 2-5 knots while the echo-sounder (Furuno FE-606 50 kHz) was operating. The echogram of the Rayong artificial reef shows that the site is dense with a structure height of about 0.5-1.5 meters (Fig. 7.3.1.3).

On the other hand, the Petchaburi artificial reef echogram shows its clean bottom, few reef marks (units or material) appear. The height of the reef is about 0.5 meter (Fig. 7.3.1.4).

The results of the observation survey show that the Rayong artificial reef is generally more effective than the Petchaburi artificial reef althrough it is 7 years older than the reef off Petchaburi. The differences between these two sites are depth (15 meters and 6 meters), bottom sediment (muddy sand and sandy), current speed (0.05 knots and 0.5-1.5 knots), and installation method (dense in small area and scattered over wide area).

Type of reef unit (various designs and single design), and location (near island and infront of long beach). This underwater observation was not successful, as expected, because the time and sea condition while conducting the survey was not supportive. Excellent teamwork among the divers is necessary for this type of survey, which requires not only a proficient diving technique but also a knowledge of marine science.

List of fishes observed by underwater visual observation:

a) Rayong Artificial Reef

	Common name	Scientific name
1.	Brown-banded catshark	*Chiloscyllium punctatum*
2.	Blue-spotted fantail ray	*Taeniura lymma*
3.	Blue-line coral cod	*Cephalopholis boenack*
4.	Bleeker's reef cod	*Epinephelus bleekeri*
5.	Sea bass grouper	*E. sexfasciatus*
6.	Greasy reef cod	*E. tauvina*
7.	Black striped snapper	*Lutjanus vitta*
8.	Gold striped snapper	*L. lineolatus*
9.	Russell's snapper	*L. russelli*
10.	Red spot emperor	*Lethrinus lentjan*

	Common name	Scientific name
11.	Painted sweetlip	*Plectorhynchus pictus*
12.	Cross-banded cardinal fish	*Archamia lineolata*
13.	Puller	*Chromis* sp.
14.	Long-nosed butterfly fish	*Chelmo rostratus*
15.	Blue Angel	*Pomacanthus annularis*
16.	Yellow-tail fusiler	*Caesio erythrogaster*
17.	Squirrel fish	*Holocentrum rubrum*
18.	Deep-body Rabbit fish	*Siganus guttatus*
19.	Blue-spotted spinefoot	*S. javus*
20.	White-spotted Rabbit fish	*S. oramin*
21.	Monocle bream	*Scolopsis ciliatus*
22.	White-cheeked monocle bream	*S. vosmeri*
23.	Bar-tailed goatfish	*Upeneus tragula*
24.	Chinese file fish	*Monacanthus chinensis*
25.	Porcupine fish	*Diodon* sp.
26.	Cleaner wrass	*Lobroides* sp.
27.	Painted moray eel	*Gymnothorax pictus*
28.	Other small fishes	

b) Petchaburi Artificial Reef

1.	Greasy reef cod	*Epinephelus tauvina*
2.	Brown-banded catshark	*Chiloscyllium punctatum*
3.	Slipmouth	*Leiognathus* sp.
4.	Slipmouth	*Scutor* sp.
5.	Trevally	*Caranx* sp.
6.	Leather jacket	*Monacanthus* sp.
7.	Leather skin	*Chorinemus* sp.

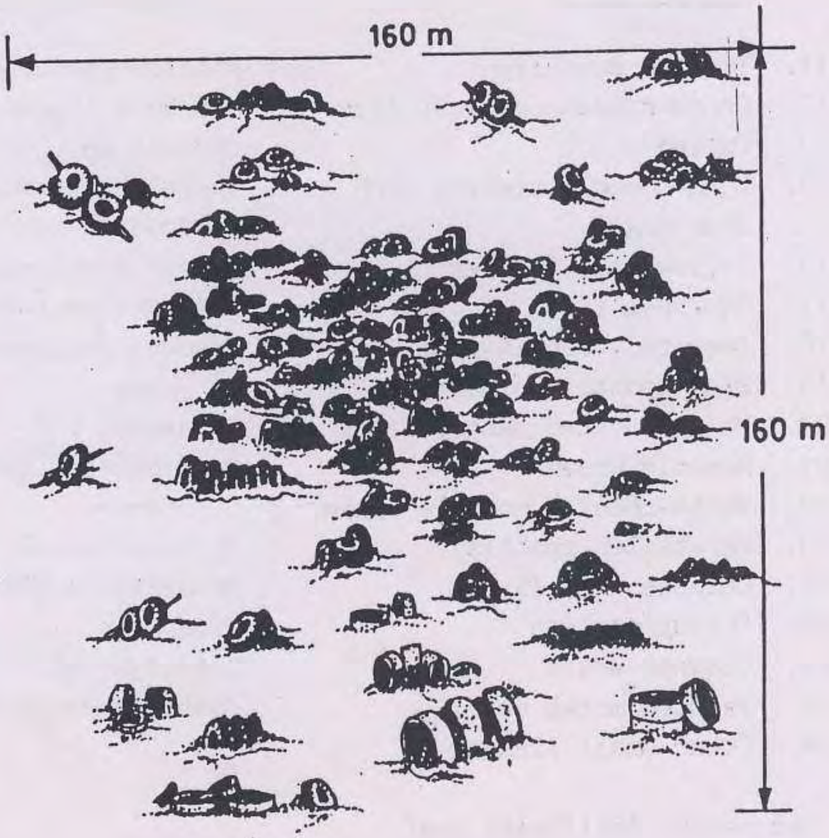


Fig. 7.3.1.1 Sketch of scattered reef off Rayong

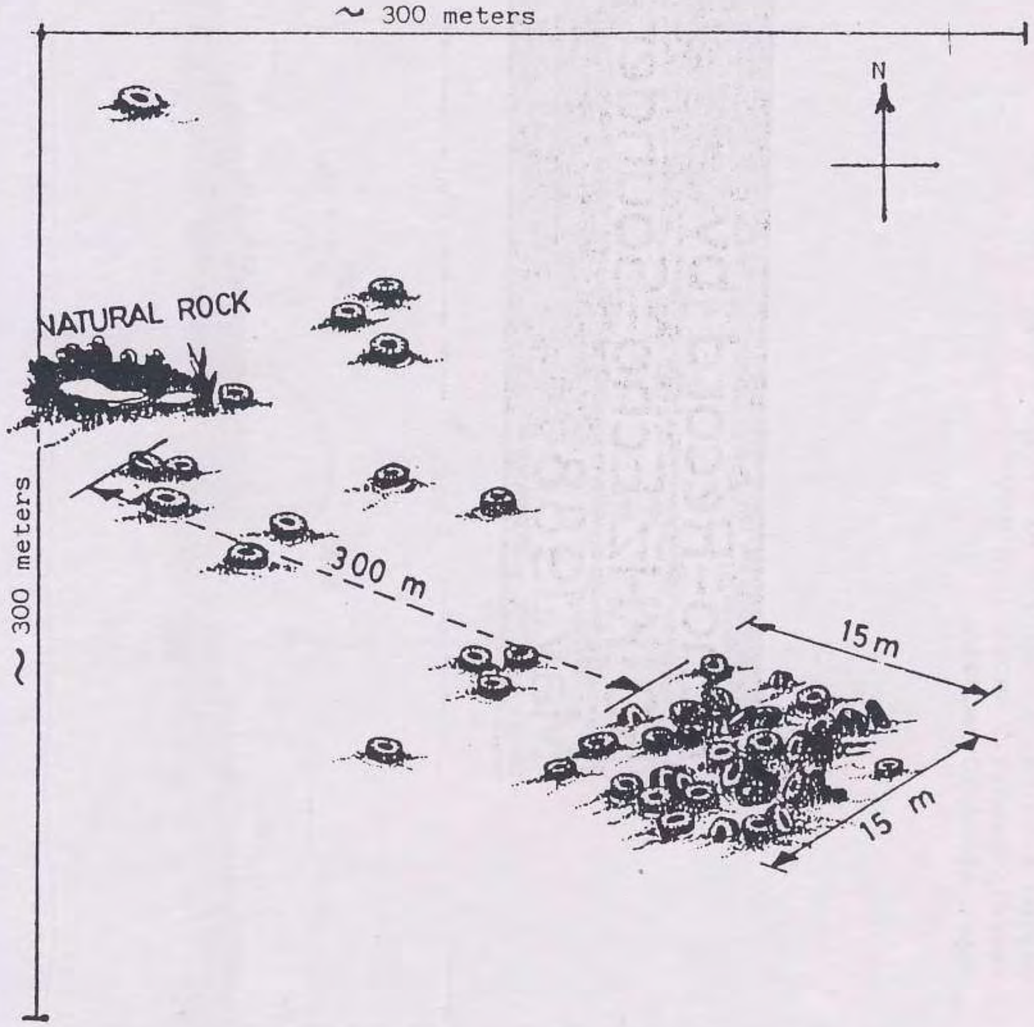


Fig. 7.3.1.2 Sketch of scattered reef off Petchaburi

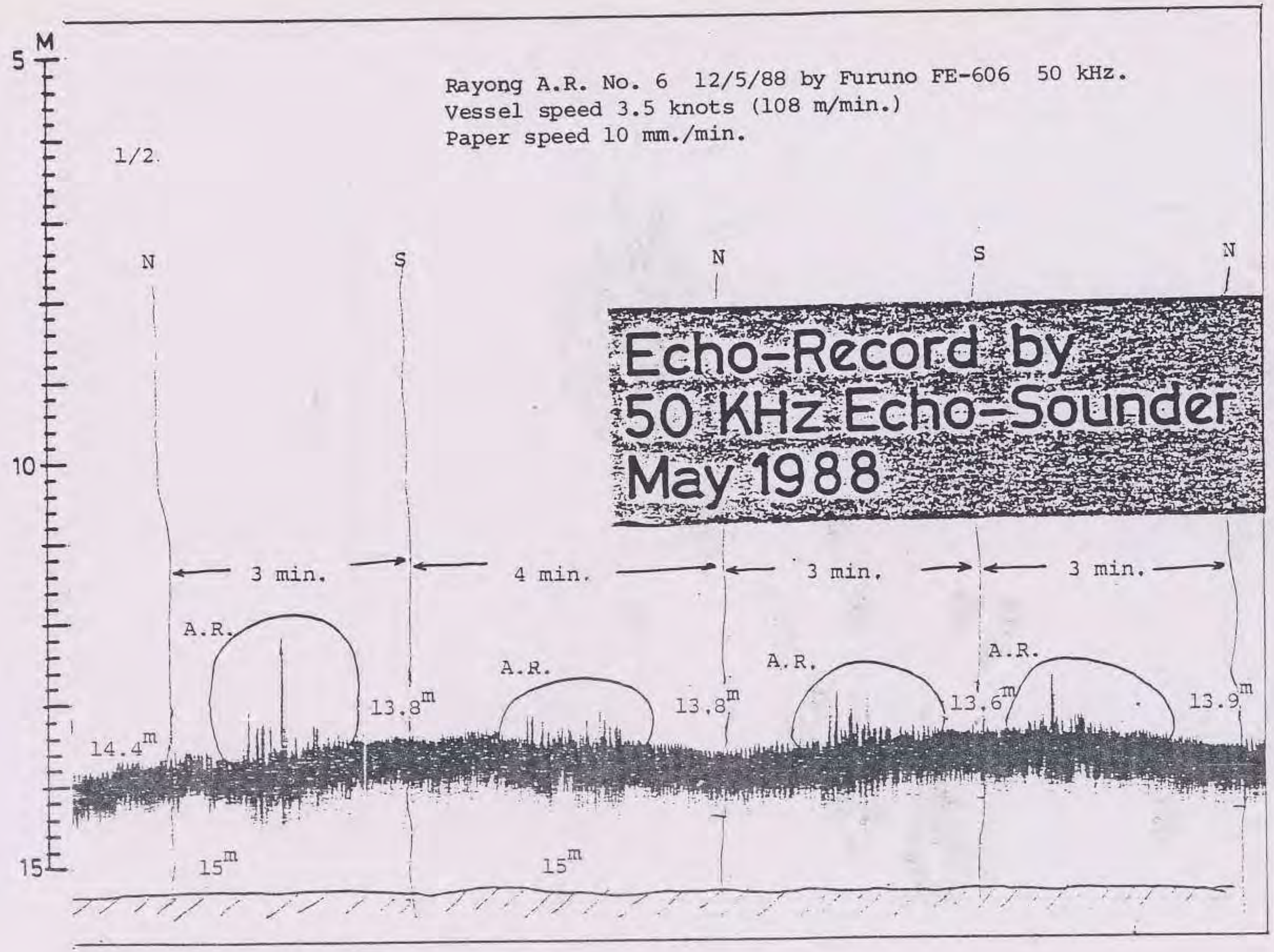


Fig. 7.3.1.3 Echogram of Rayong Artificial Reef

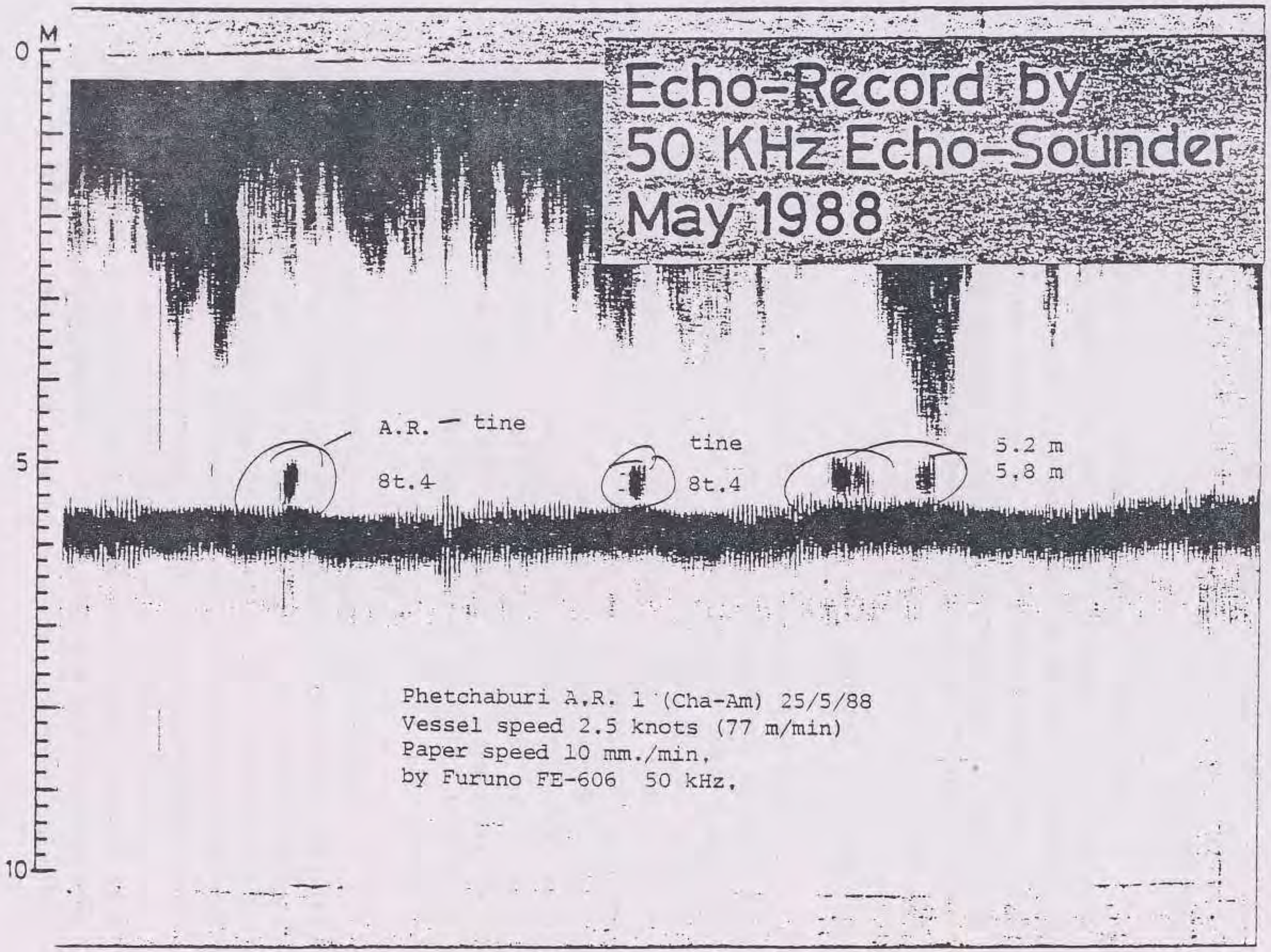


Fig. 7. .1 4 Echogram of Petchaburi Artificial Reef

7.3.2 Benthic Community Survey (by C. Aryuthaka)

Introduction

In general, benthic community is considered to be affected by the installation of the artificial reefs, and it is considered to play an important role in the ecosystem. Therefore, this survey aims to obtain data on species composition, density and community characteristics, then to examine the effect of the installation of the artificial reefs on the faunal community in the area.

Materials and Methods

The samples were collected from two sites: near Ko Man Nok, Rayong, and Cha-Am, Petchaburi. The age of the artificial reefs was eight and two years in Rayong and Petchaburi, respectively. At Ko Man Nok, Rayong, four sampling stations were selected (Fig. 7.3.2.1). Station 6 located outside the artificial reefs and the other three stations (stations 3, 4 and 5) located inside. Three sample collections were done in January, May and June 1988. Off Cha-Am, Petchaburi, samples were collected inside stations 1, 3 and 5, scattered artificial reefs, and also outside stations 6 and 7 (Fig. 7.3.2.2). The samples were collected from stations 1, 3, 6 and 7 in February 1988 and stations 1, 3, 5 and 6 in May 1988.

The sediment samples for benthic macrofauna were quantitatively collected by using a 25 cm^2 Ekman grab sampler which randomly picked up 2 replications of a 10 cm^2 quadrat, except only one sample was collected in each station in January and February. The samples were preserved in a 10% formalin solution and brought back to the SEAFDEC laboratory. At the laboratory, the sediment samples were stained with a low concentration of Rose Bengal. Then, they were sieved, passing through a 0.5 mm screen (Holme and McIntyre, 1971). The residue remaining on the sieve was observed. The animals were picked out and kept in 10%

formalin, except the crustacean groups which were kept in 70% alcohol. Then, they were identified into taxonomic groups and their number counted. No attempt at species identification was made.

With regard to encrusting fauna, the samples were qualitatively measured. They were collected by divers and put into plastic bags. On board, they were kept in a 10% formalin solution. At the laboratory, they were agitated in sea water and identified into taxonomic groups and genus level. The water was passed through a 0.5 mm sieve for identification of associated mobile animals.

Results

At the study site off Rayong, the average density of the benthic macrofauna, at all stations inside the reefs, ranged from 24 to 73, 95 to 131 and 46 to 82 individuals/100 cm^2 in January, May and June, respectively. While, at the station outside the reefs, the average density was 10, 56 and 156 individuals/100 cm^2, respectively (Table 7.3.2.1). From Fig. 7.3.2.3, the spatial distribution of these infauna in January and May shows the same pattern with higher density occurring at stations inside the reefs than outside. Unexplainably, in June, the fauna pattern changed with a slightly higher density outside than inside the reefs and an increase of density of polychaetes and amphipods.

In these infauna communities, polychaetes were dominant at nearly all stations and at all sampling times (Fig. 7.3.2.4), with a percentage of abundance between 59% to 100%. The exception, was station 6 with only 10% in January. Pelecypods, amphipods, and tanaids followed and a few sipunculids, turbellarians, ophiuroids, brachyurans, carideans, gastropods, cumaceans, *Amphioxus*, and holothuroids were found.

As for Petchaburi, it was very difficult to conclude the spatial distribution of infauna between sampling stations inside and outside the reefs because the modules were so scattered, as mentioned above. No remarkable difference of infauna density was found among the sampling stations and sampling months although, at station 1, the fauna density was higher with 159 individuals/ 100 cm^2, in February (Table 7.3.2.2). This may be because of the existence of a small natural rock formation at that station. According to faunal composition, amphipods showed a slightly higher percentage of abundance. With similarities to the faunal pattern off Rayong, however, polychaetes were mainly dominant, occupying 50% - 82%, at all stations (Table 7.3.2.2 and Fig. 7.3.2.5). The other groups of infauna were found to be similar to those off Rayong.

With regard to the similarity indices (C_π), both for Rayong and Petchaburi, the high values of indices among the sampling stations were obtained in all study months (Figs. 7.3.2.6, -7). For Rayong, although the dendrograms in Fig. 6 show a difference between the group of stations (Stations 3, 4 and 5) inside the reefs with the station outside (station 6), the dissimilarity values were infact very small. Particularly, for Petchaburi, no dissimilarity between stations inside and outside the reefs was clearly observed.

Qualitative work on encrusting organisms was done (Table 7.3.2.3). It showed the differences between those in Rayong and those in Petchaburi. Many groups of fauna existed on the modules installed off Rayong, while, off Petchaburi, mussles *(Perna viridis)* were dominant mixing with a few bryozoans and sponges. Associated mobile organisms with encrusting organisms were present in large numbers, some of them were identified to genus level. Off Rayong, caridean shrimp *(Palaemonella* sp.), dromiid crab *(Petalomera wilsoni)* and ophiuroids *(Ophiactis* sp.) were commonly found. Off Petchaburi samples which are considered similar to fauna associated with coral reefs (Prof. P. Niyanetr, personal communication), namely, alpheid shrimp (members of Fam. Alpheidae), shrimp (one species of Fam. Palaemoniidae), crab (one species of Fam. Zanthidae) and false crab (two species of Fam. Porcellanidae) were identified.

Discussion

From the oceanographical surveys, Ananpongsuk *et al.* (1988) reported that, in both site areas, the sediment textures are sand with a low percentage of silt-clay content. Furthermore, in both sites, the lack of a drastic difference in the sediment textures and nutrients inside and outside the reefs was found. In general for benthic communities, the major controlling factor in their distribution is the substratum type (Gray, 1981; Levinton, 1982 and Sanders, 1958). In this study, this factor also controls the benthic communities while showing no drastic difference in density, pattern of spatial distribution, dominant group, and fauna composition at all stations. Moreover, the dominant group in this study was polychaetes which is the common dominance for macrofauna communities on a sand bottom in the Gulf of Thailand (Gallardo, 1963; Sanguansin, 1986 and 1988). As mentioned above, it may be concluded that the artificial reef installations have had no effect on the sediment textures and macrobenthic community. However, it should be mentioned that the modules of these old reefs are scattered and lie on the bottom. These modules have been destroyed due to inadequate construction resulting from a lack of basic oceanographic information.

From this work, however, the advantage of the reef installations clearly showed resulting in an increase of substratum for encrusting organisms. Furthermore, these organisms themselves also indirectly create a complex habitat for associated animals, as mentioned in the results. The habitat complexity is an important factor in reducing predation for small associated fauna (Coull and Wells, 1983). Thus, these fauna will exist well and increase in abundance providing an important source of food for many of the fish, with special reference to omnivores and generalized carnivores such as tom tate and red snapper (Ranasinghe, 1981). However, more information on stomach content and the feeding habits of fishes is needed to confirm this.

Table 7.3.2.1 Density (ind/100 cm^2) and Percentage of Abundance (%A) of Infauna in the Study Area off Rayong

Date: Jan.'88*

Station	St.3		St.4		St.5		St.6	
Faunal taxa	D	%A	D	%A	D	%A	D	%A
Polychaete	59	80.8	24	100	58	95.0	1	10
Pelecypod	10	13.6	0	0	2	3.27	0	0
Amphipod	2	2.73	0	0	0	0	5	50
Tanaidacean	0	0	0	0	0	0	0	0
Sipunculid	0	0	0	0	0	0	0	0
Turbellarian	0	0	0	0	0	0	0	0
Ophiuroid	0	0	0	0	0	0	1	10
Brachyuran	0	0	0	0	0	0	1	10
Caridean	2	2.73	0	0	0	0	0	0
Gastropod	0	0	0	0	1	1.63	2	20
Cumacean	0	0	0	0	0	0	0	0
Amphioxus	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0
total	73	100	24	100	61	100	10	100

Date: May'88

Station	St.3 D				St.4 D				St.5 D				St.6 D			
Faunal taxa	sub1	sub2	aver	%A	sub1	sub2	aver	%A	sub1	sub2	aver	%A	sub1	sub2	aver	%A
Polychaete	71	83	77	77	55	77	66	69.8	109	94	101.5	77.7	45	21	33	58.9
Pelecypod	6	21	13.5	13.5	13	10	11.5	12.1	7	12	9.5	7.27	19	3	11	19.6
Amphipod	5	2	3.5	3.5	4	9	6.5	6.87	9	10	9.5	7.27	14	0	7	12.5
Tanaidacean	2	3	2.5	2.5	0	0	0	0	2	3	2.5	1.91	3	0	1.5	2.67
Sipunculid	0	2	1	1	4	6	5	5.29	2	5	3.5	2.68	1	1	1	1.78
Turbellarian	1	2	1.5	1.5	4	0	2	2.11	1	1	1	0.76	0	0	0	0
Ophiuroid	1	1	1	1	1	1	1	1.05	0	0	0	0	3	0	1.5	2.67
Brachyuran	0	0	0	0	1	0	0.5	0.52	2	0	1	0.76	0	0	0	0
Caridean	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropod	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacean	0	0	0	0	0	0	0	0	2	1	1.5	1.14	2	0	1	1.78
Amphioxus	0	0	0	0	2	2	2	2.11	0	0	0	0	0	0	0	0
Holothuroid	1	0	0.5	0.5	0	0	0	0	0	1	0.5	0.38	0	0	0	0
total	87	114	100	100	84	105	94.5	100	134	127	130.5	100	87	25	56	100

Date: Jun'88

Station	St.3 D				St.4 D				St.5 D				St.6 D			
Faunal taxa	sub1	sub2	aver	%A	sub1	sub2	aver	%A	sub1	sub2	aver	%A	sub1	sub2	aver	%A
Polychaete	63	29	46	83.6	62	85	73.5	90.1	40	45	42.5	93.4	111	130	120.5	77.7
Pelecypod	4	1	2.5	4.54	1	3	2	2.45	0	3	1.5	3.29	4	7	5.5	3.54
Amphipod	2	0	1	1.81	4	4	4	4.90	1	0	0.5	1.09	33	4	18.5	11.9
Tanaidacean	3	6	4.5	8.18	0	0	0	0	0	0	0	0	3	7	5	3.22
Sipunculid	0	0	0	0	0	0	0	0	1	1	1	2.19	4	1	2.5	1.61
Turbellarian	1	0	0.5	0.90	0	2	1	1.22	0	0	0	0	0	3	1.5	0.96
Ophiuroid	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.5	0.32
Brachyuran	0	0	0	0	0	1	0.5	0.61	0	0	0	0	1	1	1	0.64
Caridean	1	0	0.5	0.90	0	1	0.5	0.61	0	0	0	0	1	0	0.5	0.32
Gastropod	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacean	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphioxus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total	74	36	55	100	67	96	81.5	100	42	49	45.5	100	158	153	155.5	100

*only one replication of samples

St.3-St.5:Stations inside the artificial reefs   St.6:Station outside the artificial reefs

Table 7.3.2.2 Density (ind./100 cm^2) and Percentage of Abundance (%A) of infauna in the study area off Petchaburi

Date	Feb.'88*								May'88															
Station	St.1		St.6		St.7		St.3		St.1				St.5				St.6				St.3			
	D	%A	D	%A	D	%A	D	%A	D			%A	D			%A	D·			%A	D			%A
Faunal taxa									sub1	sub2	aver		sub1	sub2	aver		sub1	sub2	aver		sub1	sub2	aver	
Polychaete	73	45.9	20	50	30	65.2	37	64.9	26	18	22	55	4	10	7	45.1	25	19	22	80	48	20	34	81.9
Amphipod	19	11.9	12	30	8	17.3	14	24.5	0	1	0.5	1.25	1	0	0.5	3.22	3	1	2	7.27	2	1	1.5	3.61
Pelecypod	24	15.0	2	5	2	4.34	2	3.50	9	14	11.5	28.7	0	11	5.5	35.4	0	0	0	0	0	0	0	0
Tanaidacean	38	23.8	5	12.5	2	4.34	1	1.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiuroid	4	2.51	0	0	1	2.17	1	1.75	0	3	1.5	3.75	1	1	1	6.45	0	0	0	0	0	0	0	0
Brachyuran	1	0.62	1	2.5	1	2.17	0	0	0	1	0.5	1.25	0	1	0.5	3.22	1	1	1	3.63	6	1	3.5	8.43
Caridean	0	0	0	0	1	2.17	1	1.75	0	0	0	0	1	0	0.5	3.22	2	1	1.5	5.45	0	1	0.5	1.20
Turbellarian	0	0	0	0	0	0	0	0	2	3	2.5	6.25	0	0	0	0	0	0	0	0	0	0	0	0
Sipunculid	0	0	0	0	0	0	0	0	0	2	1	2.5	0	0	0	0	0	0	0	0	1	1	1	2.40
Cumacean	0	0	0	0	0	0	1	1.75	0	0	0	0	0	0	0	0	0	1	0.5	1.81	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.5	1.81	1	1	1	2.40
Pagurid	0	0	0	0	0	0	0	0	1	0	0.5	1.25	0	1	0.5	3.22	0	0	0	0	0	0	0	0
Fish(larvae)	0	0	0	0	1	2.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total	159	100	40	100	46	100	57	100	38	42	40	100	7	24	15.5	100	31	24	27.5	100	58	25	41.5	100

*only one replication of samples

St.3:Station inside the artificial reefs St.1&St.5-St.7:Stations outside the reefs

Table 7.3.2.3 List of sessile and associated mobile organisms on modules in artificial reefs

Rayong
- Bryozoans
  - *Menipea* sp.
- Sea whips
  - *Leptogorgia* sp.
- Sponges
  - Demospongiae
  - *Sycon* sp.
- Polychaetes
  - Serpulids
    - *Filograna* sp.
  - Pisionids
    - *Pisionidens* sp.
- Caridean (shrimp)
  - *Palaemonella* sp.
- Dromiidae (Crab)
  - *Petalomera wilsoni*
- Ophiuroids (brittle star)
  - *Ophiactis* sp.

Petchaburi
- Mussels
  - *Perna viridis*
- Bryozoans
  - *Menipea* sp.
- Caridean (shrimp)
- Brachyurans (small crab)

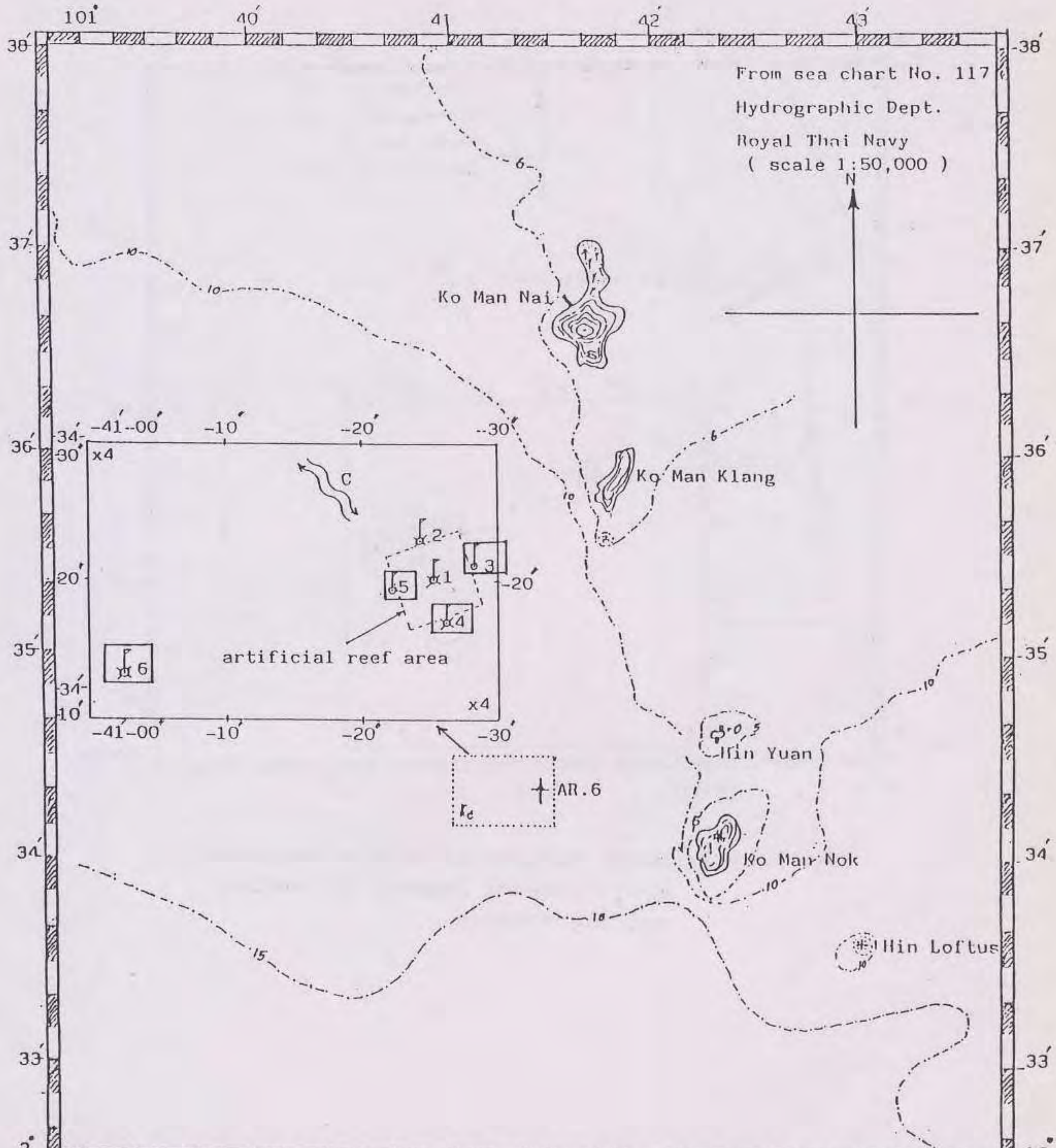


Fig. 7.3.2.1 Survey stations and area at Rayong A.R. No.6 (showing the benthos sampling stations)

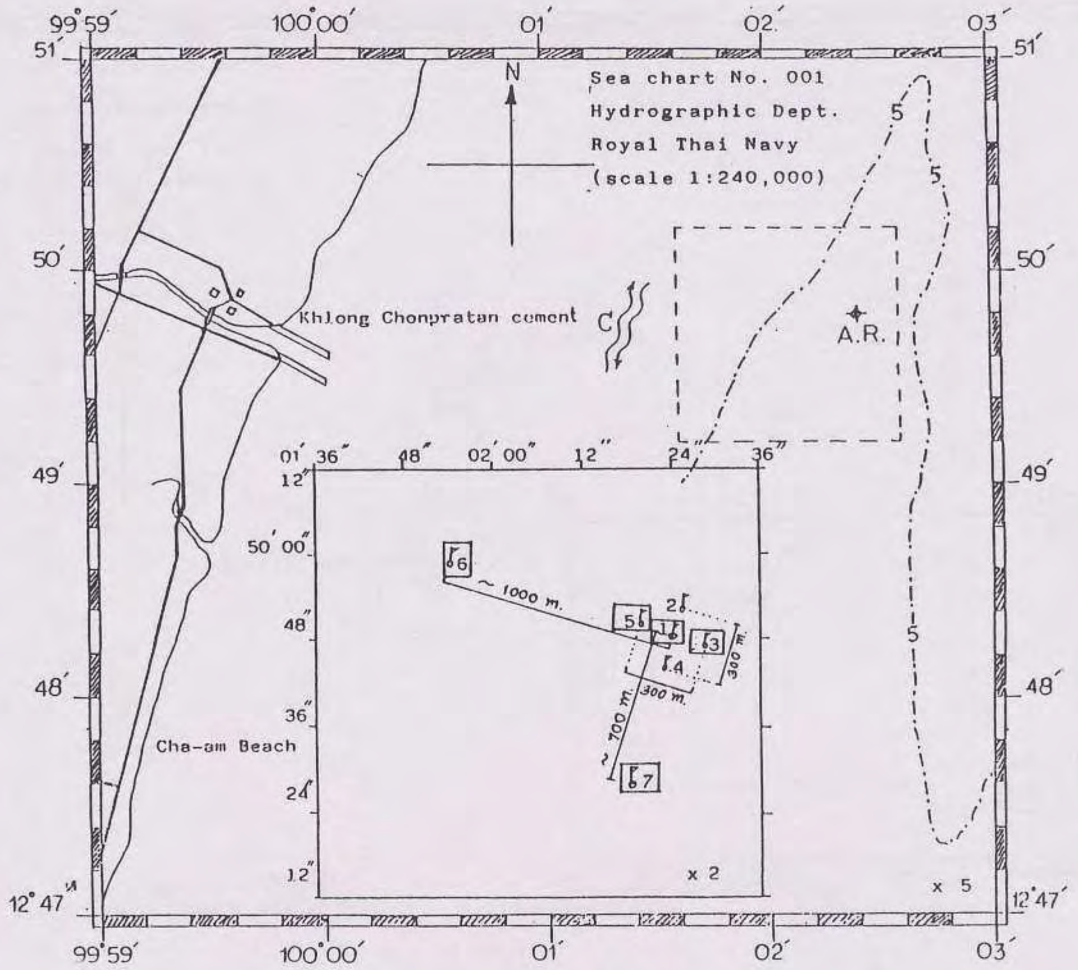


Fig. 7.3.2.2 Survey stations and area at Petchaburi A.R. 1 (Cha-am) (showing the benthos sampling stations)

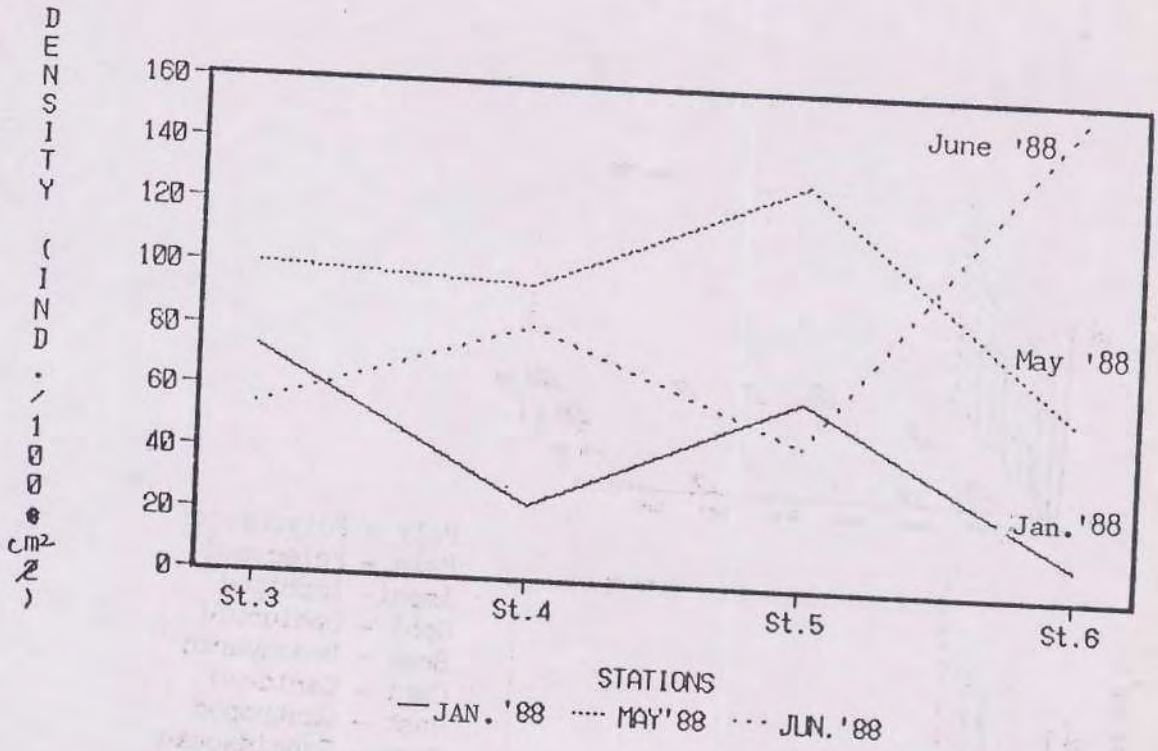
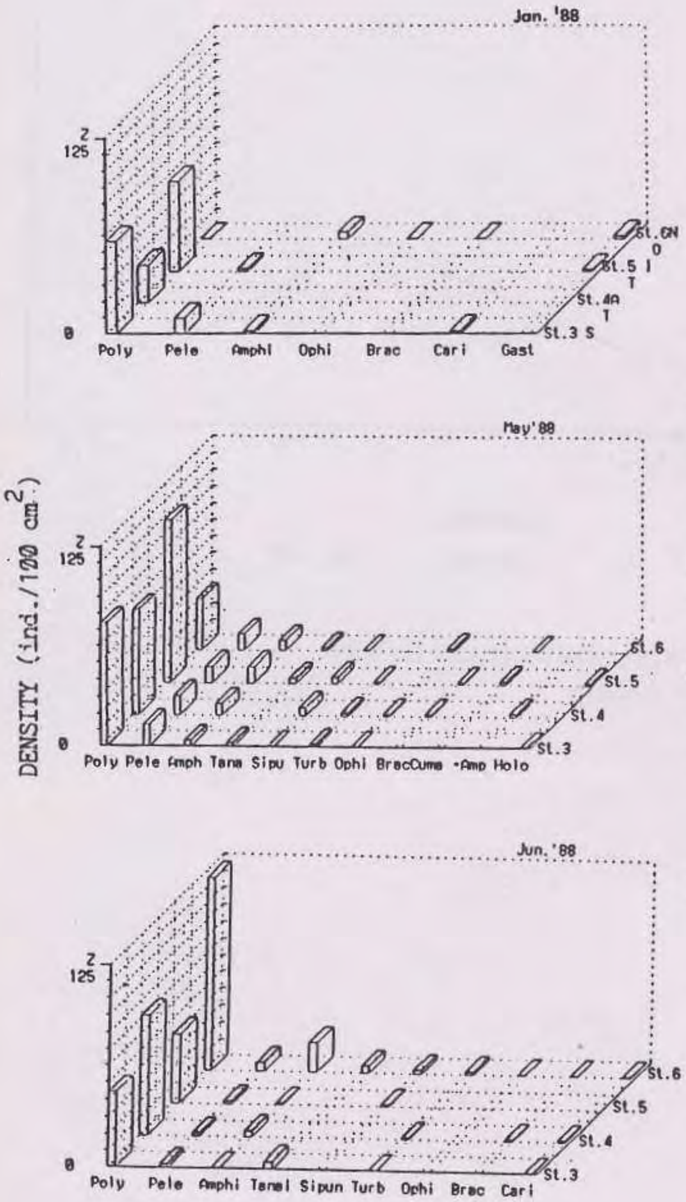


Fig. 7.3.2.3 Spatial distribution of infauna in the study area off Rayong



Poly - Polychaete
Pele - Pelecypod
Amphi- Amphipod
Ophi - Ophiuroid
Brac - Brachyuran
Cari - Caridean
Gast - Gastropod
Tana - Tanaidacean
Sipu - Sipunculid
Turb - Turbellarian
Cuma - Cumacean
Amp - *Amphioxus*
Holo - Holothuroid

St. 3-5: inside the reefs
St. 6 : outside the reefs

Fig. 7.3.2.4 Distribution pattern of infauna off Rayong

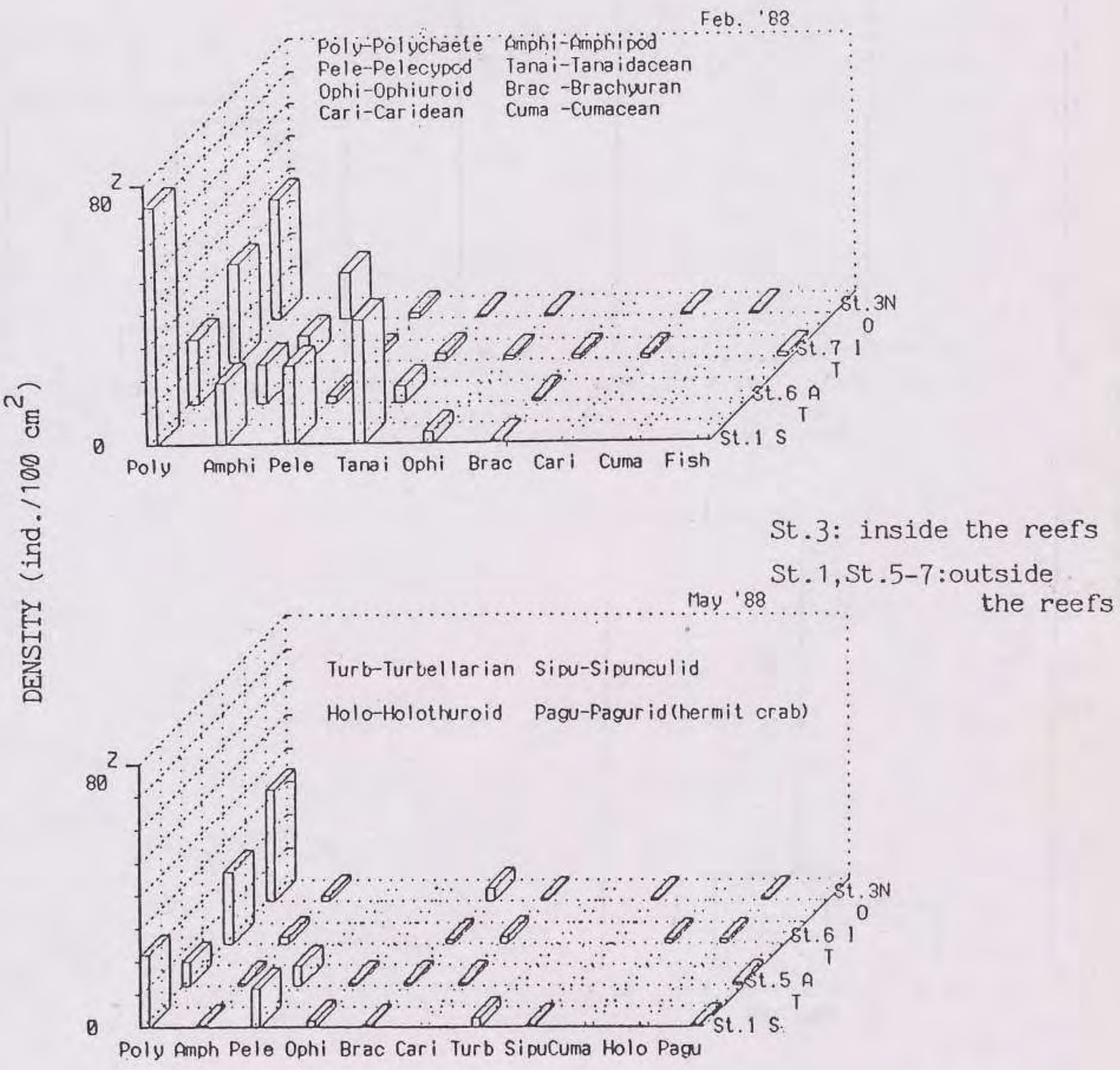


Fig. 7.3.2.5 Distribution pattern of infauna off Petchaburi

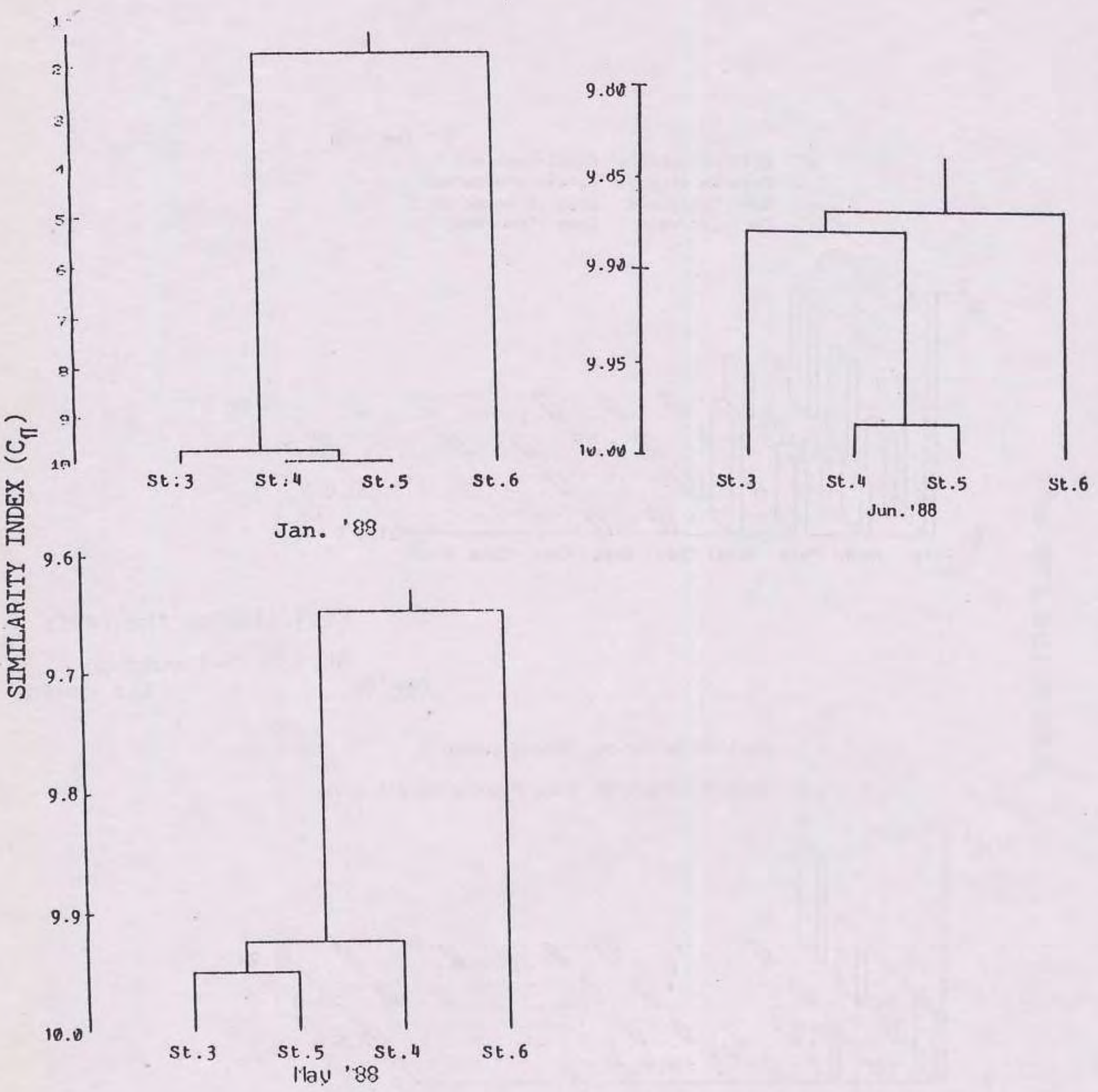


Fig. 7.3.2.6 Dendrograms clustering indices of similarity (C_{π}) of fauna community off Rayong (St. 3-5: inside the reefs, St. 6: outside the reefs)

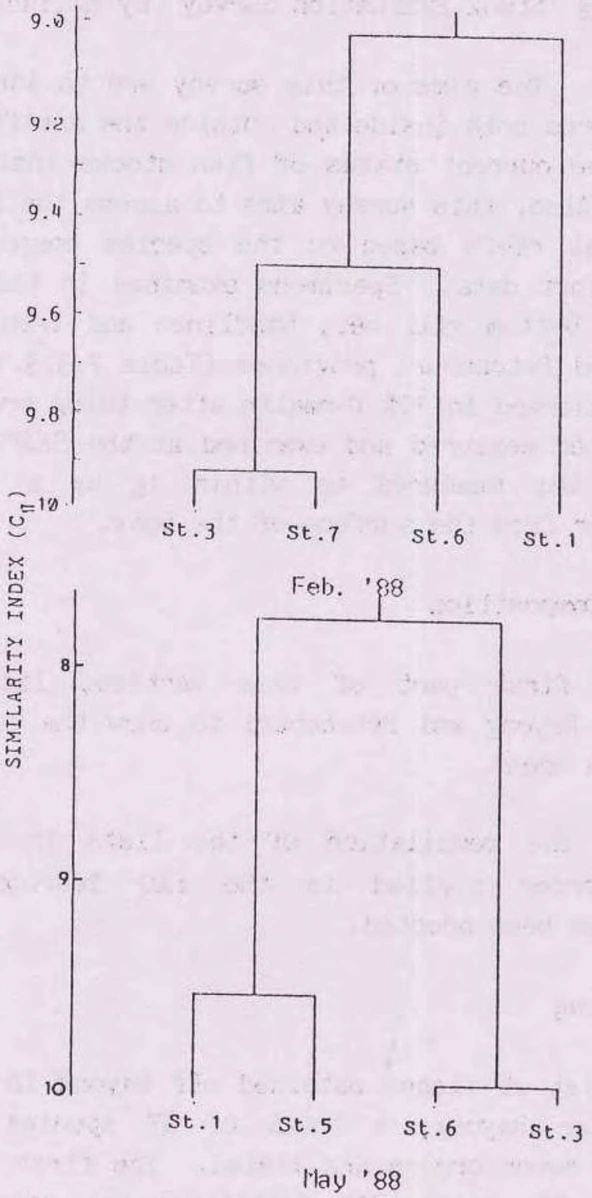


Fig. 7.3.2.7 Dendrograms clustering indices of similarity (C_π) of fauna community off Petchaburi (St. 3: inside the reefs, St. 1, St. 5-7: outside the reefs)

7.3.3 Stock Evaluation Survey (by H. Yanagawa)

The aims of this survey are to identify the fish species gathered both inside and outside the artificial reefs and to clarify the current status of fish stocks inside the artificial reefs. Also, this survey aims to assess the installation of the artificial reefs based on the species composition and the catch and effort data. Specimens examined in this section were collected by bottom gill net, handlines and traps at the sites off Rayong and Petchaburi provinces (Table 7.3.3.1, -2). Specimens were preserved in 10% formalin after being brought on board, they were later measured and examined at the SEAFDEC laboratory. Body weight was measured to within 1g by a balance, after removing water from the surface of the body.

i. Species Composition

The first part of this section, lists the fishes obtained off Rayong and Petchaburi to show the species composition in those areas.

For the compilation of the lists in this paper the systematic order applied in the FAO Yearbook of Fishery Statistics has been adopted.

(a) Rayong

A list of fishes obtained off Rayong is shown in Table 7.3.3.3. For Rayong, a total of 47 species (27 families) belonging to seven orders are listed. The first survey (January 1988) listed 31 species (22 families); the second survey (May 1988) listed 18 species (15 families), with nine newly-added species; and, the third survey (June 1988) listed 28 species (18 families) with seven newly-added species.

1st Survey

This survey only concerned fishing gear operated inside the reefs.

Bottom gill nets were operated for five hauls and 12 species belonging to 12 families (26 specimens) were caught. Blue-spotted fantail ray *(Taeniura lymma)* and squirrel fish *(Myripristis hexogonus)* were dominant with 19.2% each, followed by brown-banded catshark *(Chiloscyllium punctatum)* and small-nosed box fish *(Rhynchostracion nasus)* with 11.5% each (Appendix Table 4.1). Brown-banded catshark and blue-spotted fantail ray were found three times in five hauls, so they showed a 0.60 occurrence.

Handlines were operated seven times (one hour each) and 12 species belonging to seven families (52 specimens) were caught. Black striped snapper *(Lutjanus vitta)* was dominant with 44.2%, followed by red spot emperor *(Lethrinus lentjan*, 23.1%) and monocle bream *(Scolopsis ciliatus*, 11.5%) (Appendix Table 4.2). Black striped snapper was found in six hauls and showed a 0.86 occurrence; red spot emperor showed 0.71 and monocle bream showed 0.57.

Eight traps were operated and nine species belonging to nine families (39 specimens) were caught. Black striped snapper *(Lutjanus vitta)* and long-nosed butterfly fish *(Chelmo rostratus)* were dominant with 23.1% each, followed by bar-tailed goatfish (*Upeneus tragula*, 17.9%) and squirrel fish (*M. hexogonus*, 15.4%) (Appendix Table 4.3). Black striped snapper was found in four traps and showed a 0.50 occurrence; long-nosed butterfly fish showed 0.25.

2nd Survey

This survey concerned fishing gear operated both inside and outside the reefs.

Bottom gill nets were operated inside the reef for three hauls and seven species belonging to seven families (14 specimens) were caught. Unicorn leather jacket *(Aluterus monoceros)* was dominant with 28.6% (Appendix Table 4.4). Brown-banded catshark *(Chiloscyllium punctatum)*, red soldier fish *(Sargocentron rubrum)* , painted sweetlip *(Plectorhynchus pictus)* and unicorn leather jacket showed a 0.67 occurrence. Bottom gill nets were operated outside the reefs for three hauls, but no fish were caught (Appendix Table 4.4).

Handlines were operated inside the reefs four times (one hour each) and four species belonging to three families (60 specimens) were caught. Black striped snapper *(L. vitta)* was dominant with 63.3%, followed by red spot emperor *(Lethrinus lentjan)* with 33.3%, so almost all the specimens caught by handline inside the reefs belonged to these two species (Appendix Table 4.5). Handlines were operated once outside the reefs and three species belonging to three families (10 specimens) were caught. Sixtooth threadfin *(Nemipterus hexodon)* was dominant with 50% (Appendix Table 4.5).

Four traps were operated inside the reefs and four species belonging to four families (166 specimens) were caught. Black striped snapper *(L. vitta)* was dominant with 77.7%, followed by blue-spotted spinefoot *(Siganus javus)* with 20.5% (Appendix Table 4.6). Blue-spotted spinefoot showed a 0.50 occurrence and the others showed 0.25. Four traps were operated outside the reefs and seven species belonging to seven families (23 specimens) were caught. Blue-banded whip tail *(Pentapodus setosus)* was dominant with 34.8%, followed by lippy monocle bream *(Scolopsis temporalis)* with 21.7% (Appendix Table 4.6). These two species showed a 0.75 occurrence and unicorn leather jacket *(A. monoceros)* 0.50.

3rd Survey

This survey concerned fishing gear operated inside and outside the reefs.

Bottom gill nets were operated inside the reefs for three hauls and nine species belonging to nine families (20 specimens) were caught. Blue-spotted fantail ray *(T. lymma)* was dominant with 35.0%, followed by painted sweetlip *(Plectorhynchus pictus)* with 20.0% (Appendix Table 4.7). Blue-spotted fantail ray, red soldier fish *(S. rubrum)*, gold striped snapper *(Lutjanus lineolatus)* and painted sweetlip showed a 0.67 occurrence. Bottom gill nets were operated outside the reefs for three hauls and five species belonging to four families (12 specimens) were caught. Trevally *(Caranx macrurus)* was dominant with 58.3%, followed by two dasyatid fishes with 25.0% (Appendix Table 4.7). Trevally showed a 0.67 occurrence.

Handlines were operated inside the reefs nine times (one hour each) and 13 species belonging to seven families (139 specimens) were caught. Black striped snapper *(L. vitta)* was dominant with 44.6%, followed by gold striped snapper *(L. lineolatus)* and red spot emperor *(L. lentjan)* with 18.7% (Appendix Table 4.8). Red spot emperor was found on all nine occasions, and black striped snapper showed a 0.89 occurrence. Handlines were operated outside the reefs twice and three species belonging to three families (15 specimens) were caught. Blue-banded whip tail *(P. setosus)* was dominant with 53.3% (Appendix Table 4.8). Sixtooth threadfin *(N. hexodon)* and crescent granter *(Therapon jarbua)* were caught in each operation.

Four traps were operated inside the reef and six species belonging to five families (10 specimens) were caught. Black-spotted box fish *(Ostracion tuberculatus)* was dominant with 40.0% (Appendix Table 4.9). Black-spotted box fish showed a 0.50 occurrence. Four traps were operated outside the reefs and seven species belonging to six families (80 specimens) were caught. Cross-banded cardinal fish *(Archamia lineolata)* was dominant with 78.8% (Appendix Table 4.9). Five of the seven species showed a 0.50 occurrence.

(b) Petchaburi

A list of fishes obtained off Petchaburi is shown in Table 7.3.3.4. For Petchaburi, a total of 33 species (20 families) belonging to six orders are listed. The first survey (February 1988) listed 20 species (15 families); and, the second survey (May 1988) listed 24 species (16 families) with 13 newly added species.

1st Survey

This survey only concerned fishing gear operated inside the reefs.

Bottom gill nets were operated for two hauls and nine species belonging to eight families (150 specimens) were caught. Catshark *(Chiloscyllium griseum)* was dominant with 68.7%, followed by brown-banded catshark *(C. punctatum)* with 21.3% (Appendix Table 4.10). These two sharks together accounted for 90.0% of the total. These two shark species and blue-spotted fantail ray *(T. lymma)* were found every time.

Handlines were operated three times (one hour each) and seven species belonging to five families (19 specimens) were caught. Russell's snapper *(Lutjanus russelli)* was dominant with 31.6%, followed by silver whiting *(Sillago sihama)* with 26.3% and black striped snapper *(L. vitta)* with 15.8% (Appendix Table 4.11) Russell's snapper was found on all three occasions, and black striped snapper and monocle bream *(Scolopsis ciliatus)* showed a 0.67 occurrence.

Six traps were operated and six species belonging to six families (19 specimens) were caught. Berlenger's jewfish *(Johnius belengerii)* was dominant with 52.6%, followed by Russell's snapper *(L. russelli)* with 21.1% (Appendix Table 4.12). These two species showed a 0.67 occurrence.

2nd Survey

This survey concerned fishing gear operated both inside and outside the reefs.

Bottom gill nets were operated inside the reefs for four hauls and 13 species belonging to 12 families (217 specimens) were caught. Catshark *(C. griseum)* was dominant with 81.1%, followed by brown-banded catshark *(C. punctatum)* with 6.9% (Appendix Table 4.13). These two species of sharks were found in all four hauls; blue-spotted fantail ray *(T. lymma)* , painted sweetlip *(P. pictus)* and spotted sickle fish *(Drepane punctata)* showed a 0.75 occurrence. Bottom gill nets were operated outside the reefs for four hauls and six species belonging to four families (14 specimens) were caught. Dwarf ray *(Dasyatis imbricus)* was dominant with 35.7% , followed by catshark with 28.6% (Appendix Table 4.13). These rays and sharks showed a 0.75 occurrence.

Handlines were operated inside the reefs five times (10 hours) and eight species belonging to four families (42 specimens) were caught. Russell's snapper *(L. russelli)* was dominant with 26.2%, followed by black striped snapper *(L. vitta)* with 21.4% (Appendix Table 4.14). Russell's snapper showed a 0.80 occurrence. Handlines were operated outside the reefs once (one hour) and three species belonging to two families (five specimens) were caught. Two species of snappers accounted for 60.0% and one species of grouper for 40.0% at the total (Appendix Table 4.14).

Three traps were operated inside the reefs and seven species belonging to four families (11 specimens) were caught. Three species of snappers accounted for 45.5% (Appendix Table 4.15). Russell's snapper *(L. russelli)* showed a 0.67 occurrence. Three traps were operated outside the reefs and four species belonging to four families (four specimens) were caught (Appendix Table 4.15).

ii. Catch and Effort

For an understanding of the fishing conditions of each fishing gear at each survey area, catch and effort data obtained from inside and outside the reefs were compiled.

(a) Rayong

Bottom Gill Net (Inside Reefs)

Bottom gill nets were operated inside the reefs for three surveys (Appendix Table 4.16).

In the first survey, the fishing gear was operated for a total of 60 hours with five hauls. Catch quantity of fishes was 11,964 grams, showing 2,393 g per haul and 199 g per hour. Brown-banded catshark *(C. punctatum)* was dominant with 38.3% (4,578 g, 76.3 g/hr.), followed by blue-spotted fantail ray *(T. lymma)* with 22.4% (2,684 g, 44.7 g/hr.) and painted moray *(Gymnothorax pictus)* with 13.9% (1,659 g, 27.7 g/hr.).

In the second survey, the fishing gear was operated for a total of 36 hours with three hauls. Catch quantity of fishes was 7,870 g, showing 2,623 g per haul and 219 g per hour. Brown-banded catshark was dominant with 57.6% (4,530 g, 125.8 g/hr.), followed by blue-spotted fantail ray with 16.4% (1,295 g, 36.0 g/hr.) and unicorn leather jacket *(Aluterus monoceros)* with 16.4% (1,290 g, 35.8 g/hr.).

In the third survey, the fishing gear was operated for a total of 36 hours with three hauls. Catch quantity of fishes was 9,295 g, showing 3,098 g per haul and 258 g per hour. Blue-spotted fantail ray was dominant with 70.5% (6,552 g, 109.2 g/hr.), followed by painted sweetlip *(Plectorhynchus pictus)* with 21.5% (1,995 g, 55.4 g/hr.).

Bottom Gill Net (Outside Reefs)

Bottom gill nets were operated outside the reefs for two surveys (Appendix Table 4.17).

During the second survey, the fishing gear was operated for a total of 36 hours with three hauls. There were no fish caught outside the reefs.

During the third survey, the fishing gear was operated for a total of 36 hours with three hauls. Catch quantity of fishes was 2,770 g, showing 923 g per haul and 77 g per hour. Trevally *(Caranx macrurus)* was dominant with 58.2% (1,613 g, 44.8 g/hr.), followed by Indian flathead *(Platycephalus indicus)* with 23.0% (637 g, 17.7 g/hr.).

Handline (Inside Reefs)

Handlines were operated inside the reefs for three surveys (Appendix Table 4.18)

In the first survey, the fishing gear was operated seven times for a total of seven hours. Catch quantity of fishes was 5,644 g, showing 806 g per operation (one hour). Red spot emperor *(Lethrinus lentjan)* was dominant with 30.6% (1,727 g, 246.7 g/hr) followed by black striped snapper *(Lutjanus vitta)* with 24.1% (1,361 g, 194.4 g/hr.) and monocle bream *(Scolopsis ciliatus)* with 14.1% (795 g, 113.6 g/hr.).

In the second survey, the fishing gear was operated four times for a total of four hours. Catch quantity of fishes was 6,187 g, showing 1,547 g per operation (one hour). Black striped snapper was dominant with 63.3% (3,914 g, 978.5 g/hr.), followed by red spot emperor with 29.8% (1,845 g, 461.3 g/hr.).

In the third survey, the fishing gear was operated nine times for a total of nine hours. Catch quantity of fishes was 10,043 g, showing 1,116 g per operation (one hour). Black striped snapper was dominant with 42.8% (4,295 g, 477.2g/hr.), followed by red spot emperor with 18.8% (1,886 g, 209.6 g/hr.), and gold striped snapper *(L. lineolatus)* with 10.0% (1,002 g, 111.3 g/hr.).

Handline (Outside Reefs)

Handlines were operated outside the reefs for two surveys (Appendix Table 4.19).

During the second survey, the fishing gear was operated once for one hour. Catch quantity of fishes was 579 g, showing 579 g per operation (one hour). Sixtooth threadfin *(Nemipterus hexodon)* was dominant with 72.9% (422 g, 422 g/hr.).

During the third survey, the fishing gear was operated twice for a total of two hours. Catch quantity of fishes was 1,494 g, and showed 747 g per operation (one hour). Crescent granter *(Therapon jarbau)* was dominant with 52.7% (788 g, 394.0 g/hr.).

Trap (Inside Reefs)

Traps were operated inside the reefs for three surveys (Appendix Table 4.20).

In the first survey, eight traps operated for three days. Catch quantity of fishes was 3,546 g, showing 1,182 g per day and 443 g per trap. Painted moray *(G. pictus)* was dominant with 22.6% (801 g, 100.1 g/trap), followed by squirrel fish *(M. hexogonus)* with 18.8% (666 g, 83.3 g/trap), and then long-nosed butterfly fish *(Chelmo rostratus)* with 16.4% (582 g, 72.8 g/trap)

In the second survey, four traps were operated for three days. Catch quantity of fishes was 7,196 g, and showed 2,399 g per day and 1,799 g per trap. Gold striped snapper *(L. lineolatus)* was dominant with 59.9% (4,310 g, 1,077.5 g/trap), followed by painted moray *(G. pictus)* with 25.4% (1,829 g, 457.3 g/trap).

In the third survey, four traps were operated for three days. Catch quantity of fishes was 1,471 g, and showed 490 g per day and 368 g per trap. Blue-spotted fantail ray *(T. lymma)* was dominant with 44.3% (651 g, 162.8 g/trap), followed by painted moray with 30.9% (454 g, 113.5 g/trap).

Trap (Outside Reefs)

Traps were operated outside the reefs for two surveys (Appendix Table 4.21).

During the second survey, four traps were operated for three days. Catch quantity of fishes was 3,229 g, showing 1,076 g per day and 807 g per trap. Painted moray was dominant with 51.8% (1,672 g, 418.0 g/trap), followed by lippy monocle bream *(Scolopsis temporalis)* with 17.9% (579 g, 144.8 g/trap) and blue-banded whip tail *(Pentapodus setosus)* with 16.1% (520 g, 130.0 g/trap).

During the third survey, four traps were operated for three days. Catch quantity of fishes was 3,899 g, showing 1,300 g per day and 975 g per trap. Painted moray was dominant with 49.0% (1,912 g, 478.0 g/trap), followed by lattice monocle bream *(S. cancellatus)* with 21.3% (829g, 207.3 g/trap) and cross-banded cardinal fish *(Archamia lineolata)* with 19.7% (770 g, 192.5 g/trap).

(b) Petchaburi

Bottom Gill Net (Inside Reefs)

Bottom gill nets were operated inside the reefs for two surveys (Appendix Table 4.22).

In the first survey, the fishing gear was operated with two hauls in 26.5 hours. Catch quantity of fishes was 121,691 g, showing 60,846 g per haul and 4,592 g per hour. Catshark

(Chiloscyllium griseum) was dominant with 67.9% (82,594 g, 3,116.8 g/hr.), followed by brown-banded catshark *(C. punctatum)* with 23.0% (28,002 g, 1,056.7 g/hr.). These two sharks accounted for 90.9% of the total.

In the second survey, the fishing gear was operated with four hauls in 56 hours. Catch quantity of fishes was 184,145 g, showing 46,036 g per haul and 3,288 g per hour. Catshark was dominant with 79.2% (145,817 g, 2,603.9 g/hr.), followed by brown-banded catshark with 15.0% (27,693 g, 494.5 g/hr.). These two sharks accounted for 94.2% of the total.

Bottom Gill Net (Outside Reefs)

Bottom gill nets were operated outside the reefs for one survey (Appendix Table 4.23). During the second survey, the fishing gear was operated with four hauls for a total of 56 hours Catch quantity of fishes was 15,862 g, showing 3,966 g per haul and 283 g per hour. Two kinds of rays *(Dasyatis* sp. and *D. imbricus)* accounted for 56.1% and two kinds of shark *(C. griseum* and *C. punctatum)* accounted for 40.3%. Teleostean fishes accounted for only 3.6% of the total.

Handline (Inside Reefs)

Handlines were operated inside the reefs for two surveys (Appendix Table 4.24).

In the first survey, the fishing gear was operated three times for a total of three hours. Catch quantity of fishes was 1,316 g, and showed 439 g per operation (one hour). Russell's snapper *(Lutjanus russelli)* was dominant with 32.0% (421 g, 140.3 g/hr.), followed by silver whiting *(Sillago sihama)* with 23.0% (303 g, 101.0 g/hr.) and monocle bream *(Scolopsis ciliatus)* with 17.6% (232 g, 77.3 g/hr.).

In the second survey, the fishing gear was operated five times for a total of 10 hours. Catch quantity of fishes was 10,184 g, and showed 1,018 g per hour. Catshark *(C. griseum)* was dominant with 47.1% (4,796 g, 479.6 g/hr.), followed by greasy reef cod *(Epinephelus tauvina)* with 28.9% (2,951 g, 295.1 g/hr.). These fishes and 851 g of snappers were caught during a continuous six-hour operation at night. Others (1,586 g) were caught during four daytime operations (hours) in the usual way.

Handline (Outside Reefs)

Handlines were operated outside the reefs for one survey (Appendix Table 4.25). During the second survey, the fishing gear was operated once for one hour. Catch quantity of fishes was 398 g, and showed 398 g per operation (one hour). Bleeker's reef cod *(Epinephelus bleekeri)* accounted for 45.7% (182 g), Russell's snapper *(L. russelli)* acounted for 46.0% (183 g) and black striped snapper *(L. vitta)* accounted for 8.3% (33 g).

Trap (Inside Reefs)

Traps were operated inside the reefs for two surveys (Appendix Table 4.26).

In the first survey, six traps were operated for three days. Catch quantity of fishes was 2,899 g, and showed 966 g per day and 483 g per trap. Russell's snapper *(L. russelli)* was dominant with 35.1% (1,018 g, 169.7 g/trap), followed by catshark *(C. griseum)* with 24.7% (716 g, 119.3 g/trap) and Berlenger's jewfish *(Johnius belengerii)* with 20.0% (580 g, 96.7 g/trap).

In the second survey, three traps were operated for three days. Catch quantity of fishes was 1,376 g, and showed 459 g per trap (day). Greasy reef cod *(Epinephelus tauvina)* was dominant with 38.4% (528 g, 176.0 g/trap), followed by Chinese file fish *(Monacanthus chinensis)* with 24.3% (334 g, 111.3 g/trap).

Trap (Outside Reefs)

Traps were operated outside the reefs for one survey (Appendix Table 4.27). During the second survey, three traps were operated for three days. Catch quantity of fishes was 245 g, and showed 82 g per trap (day). Chinese file fish accounted for 31.0% (76 g, 25.3 g/trap), Russell's snapper for 29.8% (73 g, 24.3 g/trap), banded jewfish *(Johnius carutta)* for 27.8% (68 g, 22.7 g/trap) and greasy reef cod for 11.4% (28 g, 9.3 g/trap).

iii. Comparisons of Inside and Outside the Reefs

The present status of fish species composition and catch and effort of each fishing gear both inside and outside the reefs is clear. But, the differences in the conditions inside and outside the reefs are not clear. It can be considered that the evaluation of the artificial reefs will mainly depend on the comparisons of some conditions inside and outside the reefs from the point of view of the biological survey. Therefore, some comparisons were done to ascertain the efficiency of the artificial reefs as fishing grounds.

(a) Relationship Between Fishing Gear and Species Composition

Before comparing the conditions inside and outside the reefs, relationships between three kinds of fishing gear and species compositions at family level were examined using the χ^2 test.

Rayong

The results of the significance test for Rayong are shown in Table 7.3.3.5.

- Inside the Reefs -

In the first survey, species belonging to 12 families were caught by bottom gill nets; seven families by handlines; 10 families by traps. Lutjanid fishes were dominant with 32 specimens, and muraenid fishes were found in all three kinds of fishing gear. Specimens obtained from the first survey showed a significant difference at the 1% level, which suggested that the species composition was related to individual fishing gear.

In the second survey, species belonging to seven families were caught by bottom gill nets; three families by handlines; four families by traps. Lutjanid fishes were dominant with 167 specimens, and no one family was found in all three kinds of fishing gear. Specimens obtained from the second survey showed a significant difference at the 1% level, which suggested the different functions of the fishing gears.

In the third survey, species belonging to nine families were caught by bottom gill nets; seven families by handlines; five families by traps. Lutjanid fishes were dominant with 95 specimens; holocentrid and lutjanid fishes were found in all three kinds of fishing gear. Specimens obtained from the third survey showed a significant difference at the 1% level, suggesting the different functions of the fishing gears.

- Outside the Reefs -

During the second survey, no specimens were caught by bottom gill nets, but three families were caught by handlines and seven families by traps. Nemipterid and pentapodid fishes were dominant with 10 specimens each. Specimens obtained from handlines and traps in the second survey showed no significant difference ($0.10 > P > 0.05$).

During the third survey, species belonging to four families were caught by bottom gill nets; three families by handlines; six families by traps. Apogonid fishes were dominant with 63 specimens, and nemipterid fishes were found in all three kinds of fishing gear. Specimens obtained from the third survey showed a significant difference at the 1% level, which suggested the different function of the fishing gears.

Petchaburi

The results of the significance test for Petchaburi are shown in Table 7.3.3.6.

- Inside the Reefs -

In the first survey, species belonging to eight families were caught by bottom gill nets; five families by handlines; six families by traps. Orectolobid fishes were dominant with 136 specimens, and lutjanid fishes were found in all three kinds of fishing gear. Specimens obtained from the first survey showed a significant difference at the 1% level, which suggested that the species composition was related to individual fishing gear.

In the second survey, specimens belonging to 12 families were caught by bottom gill nets; four families by handlines; four families by traps. Orectolobid fishes were dominant, and lutjanid fishes were found in all three kinds of fishing gear. Specimens obtained from the second survey showed a significant difference at the 1% level, which suggested the different functions of the fishing gears.

- Outside the Reefs -

During the second survey, species belonging to four families were caught by bottom gill nets; two families by hand-lines; four families by traps. Orectolobid and dasyatid fishes were dominant with six specimens each, and lutjanid fishes were found in all three kinds of fishing gear. Specimens obtained from the second survey showed a significant difference at the 1% level, which suggested the different functions of the fishing gears.

(b) Comparison of Species Composition Inside and Outside the Reefs

It became clear that each fishing gear has distinct characteristics which affect the species composition. Therefore, comparisons of species composition inside and outside the reefs were done on the basis of individual fishing gear using the χ^2 test.

Rayong

A comparison of species composition inside and outside the reefs in Rayong was made (Table 7.3.3.7).

- Bottom Gill Net -

There were no fish caught during the second survey outside the reefs. So, a comparison was done only during the third survey. There was a significant difference in species composition at the 5% level inside and outside the reefs. The difference was mainly due to lutjanid and pomadasid fishes.

- Handline -

There was a significant difference in species composition at the 1% level inside and outside the reefs during the second survey. The difference was mainly due to lutjanid and nemipterid fishes. During the third survey, there was a significant difference in species composition at the 5% level. The difference was mainly due to lutjanid and pentapodid fishes.

- Trap -

There was a significant difference in species composition at the 1% level inside and outside the reefs during the second survey. The difference was mainly due to lutjanid, pentapodid and siganid fishes. During the third survey, there was a significant difference in the species composition at the 1% level. The difference was mainly due to nemipterid and ostraciontid fishes.

Petchaburi

A comparison of species compositions inside and outside the reefs in Petchaburi was made (Table 7.3.3.8).

- Bottom Gill Net -

There was a significant difference in species composition at the 1% level inside and outside the reefs. The difference was mainly due to orectolobid fishes which accounted for over 90% of the total.

- Handline and Trap -

There was no significant difference in species composition inside and outside the reefs, which suggested that species composition of the catch from handlines and traps was not affected by the existence of the artificial reefs.

(c) Comparison of Catch Quantity

Catch quantity per unit effort (CPUE) of each fishing gear group was examined using a *t*-test. Each examination used the data from inside and outside the reefs off Rayong and Petchaburi.

Bottom Gill Net

Mean values (CPUE) for each survey are shown in Fig. 7.3.3.1. Three groups were formed by the mean values for bottom gill nets. The first group consisted of Outside the Reefs off Rayong (462 g/haul). The second group consisted of Inside the Reefs off Rayong (2,648 g/haul) and Outside the Reefs off Petchaburi (3,966 g/haul). The third group consisted of Inside the Reefs off Petchaburi (50,973 g/haul).

Handline

Mean values (CPUE) for each survey are shown in Fig. 7.3.3.1. Three groups were formed by the mean values for handlines. The first group consisted of Outside the Reefs off Petchaburi (398 g/hour; one operation only). The second group consisted of Inside the Reefs off Petchaburi (542 g/hour) and Outside the Reefs off Rayong (691 g/hour). The third group consisted of Outside the Reefs off Rayong (691 g/hour) and Inside the Reefs off Rayong (1,094 g/hour).

Trap

Mean values (CPUE) for each survey are shown in Fig. 7.3.3.1. Two groups were formed by the mean values for traps. The first group consisted of Outside the Reefs off Petchaburi (82 g/trap) and Inside the Reefs off Petchaburi (475 g/trap). The second group consisted of Inside the Reefs off Petchaburi (475 g/trap), Inside the Reefs off Rayong (763 g/trap) and Outside the Reefs off Rayong (891 g/trap).

iv. Discussion

For this part of the evaluation, lists of fishes obtained off Rayong and Petchaburi were compiled. Then, we examined the species compositions by survey, fishing gear and inside/outside the reefs. From the results of the survey, 47 species belonging to 27 families were listed off Rayong. On the fish species compositions off Rayong, Sinanuwong *et al.* (1986) carried out surveys around units 5 and 6 of the artificial reefs using handlines, fish traps and diving observations. In comparing their results for unit 6 with our survey (same area), many species were found to be common to each. Specifically, the percentage of catches by handline showed a similar trend of species composition in both results. So, it is considered that targetted fishery species and gathered species at the area of the artificial reefs off Rayong became clearer by adding to the present work both species which were reported by Sinanuwong *et al.* (1986).

For assessment of the installation of the artificial reefs, we compared the species composition and catch & effort inside and outside the reefs.

For computation of indices of diversity and similarity of fish communities, obtained from various fishing grounds, the methods formulated by Simpson (1949), Morishita (1959) and Kimoto (1967) are often used. In the Gulf of Thailand, Hayase *et al.* (1985) compared species composition obtained by bottom trawler in different periods using these indices. In general, it can be assumed that species composition of catches obtained by concerted fishing efforts showed species composition closely following the natural distribution (Yoshihara, 1987). Therefore, computing the indices of diversity and similarity is a useful method of comparing species composition of catches collected by such fishing gear and effort. However, because of the limited data obtained in this survey, it must be considered that the species composition of the catches does not accurately represent the natural distribution of species composition in these areas. So, for comparison of species composition inside and outside the reefs, we examined the pattern of species composition of catches caught by individual bottom gill nets, handlines and traps, under almost identical fishing conditions.

Before analyzing these, we first determined whether we should use the data from individual fishing gear or the combined data from all the fishing gears. Results from the above determination showed that it was better to use data from individual fishing gear, because each fishing gear has distinct characteristics affecting species composition.

At family level, species composition of bottom gill nets, handlines and traps showed significant differences inside and outside the reefs, with the exception of bottom gill nets, which showed no catch outside the reefs, in the second survey off Rayong. Off Petchaburi, however, species composition for handlines and traps showed no significant differences, whereas that of bottom gill nets showed significant differences inside and outside the reefs. The significant difference shown by bottom gill nets can be considered mainly due to the many specimens of sharks affecting the comparisons of species composition. Specifically, sharks accounted for over 90% of total catch in number. Comparing the species composition of bottom gill nets inside and outside the reefs (but excluding the sharks), we saw no significant difference between them (χ^2 = 9.387, df = 10, $0.50 > P > 0.25$)

From the above results (concluded results are shown in Table 7.3.3.9), for Rayong, it was clear that a new environmental condition has been established inside the reefs which is different from the outside areas. And it was assumed that the installation of the artificial reefs has acted positively in creating new fish communities. On the other hand, for Petchaburi, no significant difference in species composition of teleostean fishes inside and outside the reefs was shown, so the artificial reefs have been working insufficiently in creating new fish communities, with the exception of providing habitats for two kinds of shark.

For the catch quantity, the CPUEs of bottom gill nets showed wide variations, from 462 to 50,973 g/haul due to large quantities of the two sharks, especially off Petchaburi. Also, it became clear that CPUEs inside reefs were significantly higher than those outside reefs, both for Rayong and Petchaburi. On the other hand, CPUEs of handlines and traps did not show such variations as bottom gill nets. For these two kinds of fishing gear, catch quantities off Rayong were higher than those off Petchaburi. Handlines, outside the reefs off Rayong (691 g/hr.) and inside the reefs off Petchaburi (542 g/hr.) shared the same CPUE group. Traps, outside the reefs off Rayong (891 g/trap) showed the highest value, almost double that inside the reefs off Petchaburi (475 g/trap). From these results of catch quantity (see Fig. 7.3.3.2), we can say that the catch quantity outside the reefs off Rayong was higher than inside the reefs off Petchaburi, with however, no significant difference, for handlines and traps. We can, therefore, assume that installation of the artificial reefs off Rayong acted positively to gather fishes. But, the artificial reefs off Petchaburi did not act like those off Rayong.

The installation of the artificial reefs off Rayong could be considered efficient, based on the results of species composition and catch quantity. However, we could not compare these results with other information on estimated annual average productivity (e.g. SCSP 1978, reported that demersal resources on the shelf area of the Gulf of Thailand were 3.85 mt/km^2 p.a.).

Kanamori (1984) stated that the artificial reefs which are installed for less resource-populated areas, attract fewer fish species and low fishing effort areas show, of course, smaller catches per m^3. But it is considered important that we evaluate artificial reefs as effective if the value of targetted species are higher. Higher priced species, on the basis of market price (FMO, 1987), listed in these surveys, are marine catfishes *(Plotosus)*, groupers *(Epinephelus)* , whitings *(Sillago)* , trevallies *(Caranx)*, snappers *(Lutjanus)*, threadfin breams *(Nemipterus)*, sweetlips *(Plectorhynchus)* , flatfishes *(Pseudorhombus)* and jewfishes *(Johnius)* . From this point of view, we can consider that it is better to concentrate fishing on higher priced fish species like those above mentioned, especially in the areas where we cannot expect a rapid increase in resources.

In summary, we can evaluate the installation of the artificial reefs off Rayong (unit 6) as moderately effective from the point of view of species composition and comparisons of catch quantity. This is because, the artificial reefs have been establishing new fish communities inside the reefs and showed higher catch quantities than outside the reefs, with few exceptions. However, it could not be ascertained whether the artificial reefs work more efficiently than the other ordinary fishing grounds. As for the artificial reefs off Petchaburi, we were unable to evaluate them as effective from the point of view of this survey.

Table 7.3.3.1 Rayong Fishing Operations

Survey	Area	Fishing gear	Gear operation	
1st survey (25-29 Jan. 1988)	Inside reefs	Bottom gill net Handline Trap	5 hauls 7 times 8 traps	60 hours 7 hours 3 days
	Outside reefs	-	-	-
2nd survey (9-13 May 1988)	Inside reefs	Bottom gill net Handline Trap	3 hauls 4 times 4 traps	36 hours 4 hours 3 days
	Outside reefs	Bottom gill net Handline Trap	3 hauls 1 time 4 traps	36 hours 1 hour 3 days
3rd survey (13-17 June 1988)	Inside reefs	Bottom gill net Handline Trap	3 hauls 9 times 4 traps	36 hours 9 hours 3 days
	Outside reefs	Bottom gill net Handline Trap	3 hauls 2 times 4 traps	36 hours 2 hours 3 days

Table 7.3.3.2 Petchaburi Fishing Operations

Survey	Area	Fishing gear	Gear operation	
1st survey (1-5 Feb. 1988)	Inside reefs	Bottom gill net Handline Trap	2 hauls 3 times 6 traps	26.5 hours 3 hours 3 days
	Outside reefs	-	-	-
2nd survey (23-27 May 1988)	Inside reefs	Bottom gill net Handline Trap	4 hauls 5 times 3 traps	56 hours 10 hours 3 days
	Outside reefs	Bottom gill net Handline Trap	4 hauls 1 time 3 traps	56 hours 1 hour 3 days

Table 7.3.3.3 List of fishes collected inside and outside the reefs off Rayong. 1, first survey; 2, second survey; 3, third survey; I, inside reefs; 0, outside reefs. (During the first survey fishing gear operations were done inside the reefs only)

Lamniformes			
Orectolobidae			
Chiloscyllium punctatum	1(I)	2(I)	
Rajiformes			
Dasyatidae			
Dasyatis imbricatus			3(0)
Dasyatis sp.			3(0)
Taeniura lymma	1(I)	2(I)	3(I)
Anguilliformes			
Anguilloidei			
Muraenidae			
Gymnothorax pictus	1(I)	2(I,0)	3(I,0)
Beryciformes			
Holocentridae			
Myripristis hexagonus	1(I)		
Sargocentron rubrum		2(I)	3(I)
Perciformes			
Percoidei			
Serranidae			
Epinephelus megachir	1(I)	2(I)	
Epinephelus bleekeri	1(I)	2(I,0)	3(I)
Cephalopholis pachycentron	1(I)		
Cephalopholis boenack	1(I)		3(I)
Latidae			
Psammoperca waigiensis	1(I)		
Apogonidae			
Archamia lineolata	1(I)		3(0)
Carangidae			
Caranx macrurus	1(I)		3(I,0)
Selaroides leptolepis		2(I)	
Lutjanidae			
Lutjanus russelli			3(I)
Lutjanus vitta	1(I)	2(I,0)	3(I)
Lutjanus lineolatus		2(I)	3(I)
Caesio erythrogaster	1(I)		
Nemipteridae			
Nemipterus tolu	1(I)		
Nemipterus hexodon		2(0)	3(I,0)
Scolopsis cancellatus			3(I,0)
Scolopsis ciliatus	1(I)		3(I)
Scolopsis dubiosus			3(I)
Scolopsis temporalis		2(0)	3(I,0)
Pentapodidae			
Pentapodus setosus		2(0)	3(I,0)

Table 7.3.3.3 (Continued)

Leiognathidae			
Secutor indicius	1(I)		
Pomadasyidae			
Plectorhynchus pictus	1(I)	2(I,0)	3(I)
Theraponidae			
Therapon jarbua		2(0)	3(0)
Lethrinidae			
Lethrinus lentjan	1(I)	2(I)	3(I)
Mullidae			
Upeneus tragula	1(I)		3(0)
Monodactylidae			
Monodactylus argenteus	1(I)		
Ephippidae			
Platax teira	1(I)		
Chaetodontidae			
Chelmo rostratus	1(I)		
Labridae			
Choerodon schoenleini	1(I)		
Halichoeres nigrescens	1(I)		
Siganoidei			
Siganidae			
Siganus oramin	1(I)		3(I,0)
Siganus javus	1(I)	2(I)	
Siganus guttatus	1(I)		
Scombroidei			
Scombridae			
Rastrelliger kanagurta		2(I)	
Cottoidei			
Scorpaenidae			
Scorpaenopsis cirrhosa	1(I)		
Platycephalidae			
Platycephalus indicus			3(0)
Pleuronectiformes			
Pleuronectoidei			
Bothidae			
Pseudorhombus elevatus	1(I)		3(I)
Tetrodontiformes			
Balistoidei			
Aluteridae			
Aluterus monoceros		2(I,0)	
Monacanthus chinensis			3(0)
Ostracioidei			
Ostraciontidae			
Rhynchostracion nasus	1(I)		3(I)
Ostracion tuberculatus	1(I)		3(I)

Table 7.3.3.4 List of fishes collected inside and outside the reefs off Petchaburi. 1, first survey; 2, second survey; I, inside reefs; 0, outside reefs. (During the first survey, fishing gear operations were done inside the reefs only)

Lamniformes		
Orectolobidae		
Chiloscyllium punctatum	1(I)	2(I,0)
Chiloscyllium griseum	1(I)	2(I,0)
Rajiformes		
Dasyatidae		
Dasyatis imbricus		2(0)
Dasyatis sp.		2(0)
Taeniura lymma	1(I)	2(I)
Myliobatidae		
Aetobatus narinari		2(I)
Cypriniformes		
Siluroidei		
Plotosidae		
Plotosus canius	1(I)	
Perciformes		
Percoidei		
Serranidae		
Cephalopholis pachycentron		2(I)
Epinephelus tauvina	1(I)	2(I,0)
Epinephelus sexfasciatus	1(I)	
Epinephelus bleekeri		2(I,0)
Sillaginidae		
Sillago sihama	1(I)	2(I)
Sillago maculata	1(I)	
Carangidae		
Atule djeddaba	1(I)	
Atule mate	1(I)	2(I)
Lutjanidae		
Lutjanus russelli	1(I)	2(I,0)
Lutjanus vitta	1(I)	2(I,0)
Lutjanus lineolatus		2(I)
Lutjanus johni		2(I)
Nemipteridae		
Scolopsis ciliatus	1(I)	
Leiognathidae		
Leiognathus fasciatus	1(I)	
Leiognathus brevirostris		2(I)
Pomadasyidae		
Plectorhynchus pictus	1(I)	2(I)

Table 7.3.3.4 (Continued)

Sciaenidae		
Johnius carutta		2(I,0)
Johnius belengerii	1(I)	
Ephippidae		
Drepane punctata		2(I)
Chaetodontidae		
Chelmo rostratus	1(I)	
Scatophagidae		
Scatophagus argus	1(I)	2(I)
Siganoidei		
Siganidae		
Siganus javus		2(I)
Tetrodontiformes		
Balistoidei		
Aluteridae		
Monacanthus chinensis	1(I)	2(I,0)
Ostracioidei		
Ostraciontidae		
Ostracion tuberculatus		2(I)
Tetraodontoidei		
Diodontidae		
Diodon liturosus		2(I)
Batrachoidiformes		
Batrachoididae		
Halophryne trispinosus	1(I)	

Table 7.3.3.5 Significance test of relationship between three kinds of fishing gear and species composition at family level both inside and outside the reefs off Rayong

Rayong		χ^2	df	P
Inside reefs	1st survey	130.254	34	P < 0.005
	2nd survey	289.699	20	P < 0.005
	3rd survey	193.200	24	P < 0.005
Outside reefs	1st survey	-	-	-
	2nd survey*	13.587	7	0.10 > P > 0.05
	3rd survey	182.903	20	P < 0.005

*Handline and Trap only

Table 7.3.3.6 Significance test of relationship between three kinds of fishing gear and species composition at family level both inside and outside the reefs off Petchaburi.

Petchaburi		χ^2	df	P
Inside reefs	1st survey	272.109	24	P < 0.005
	2nd survey	277.942	26	P < 0.005
Outside reefs	1st survey	-	-	-
	2nd survey	23.969	10	0.010 > P > 0.005

Table 7.3.3.7 Comparison of species composition at family level, of fish caught by three kinds of fishing gear, inside and outside the reefs off Rayong

Rayong		χ^2	df	P
2nd survey	B. gill net	-	-	-
	Handline	25.000	5	$P < 0.005$
	Trap	150.343	8	$P < 0.005$
3rd survey	B. gill net	17.173	9	$0.050 > P > 0.025$
	Handline	18.458	7	$0.025 > P > 0.010$
	Trap	82.406	9	$P < 0.005$

Table 7.3.3.8 Comparison of species composition at family level, of fish caught by three kinds of fishing gear, inside and outside the reefs off Petchaburi

Petchaburi		χ^2	df	P
2nd survey	B. gill net	51.037	11	$P < 0.005$
	Handline	1.745	2	$0.500 > P > 0.250$
	Trap	3.920	4	$0.500 > P > 0.250$

Table 7.3.3.9 Concluded results of comparisons of species composition at family level inside and outside the reefs. (NS, not significant; * significant at the 5% level; ** significant at the 1% level)

Survey	Fishing gear	Inside vs Outside
Rayong 2nd Survey	Bottom gill net Handline Trap	- ** **
Rayong 3rd Survey	Bottom gill net Handline Trap	* * **
Petchaburi 2nd Survey	Bottom gill net Handline Trap	NS[1)] NS NS

1) Excluding the shark

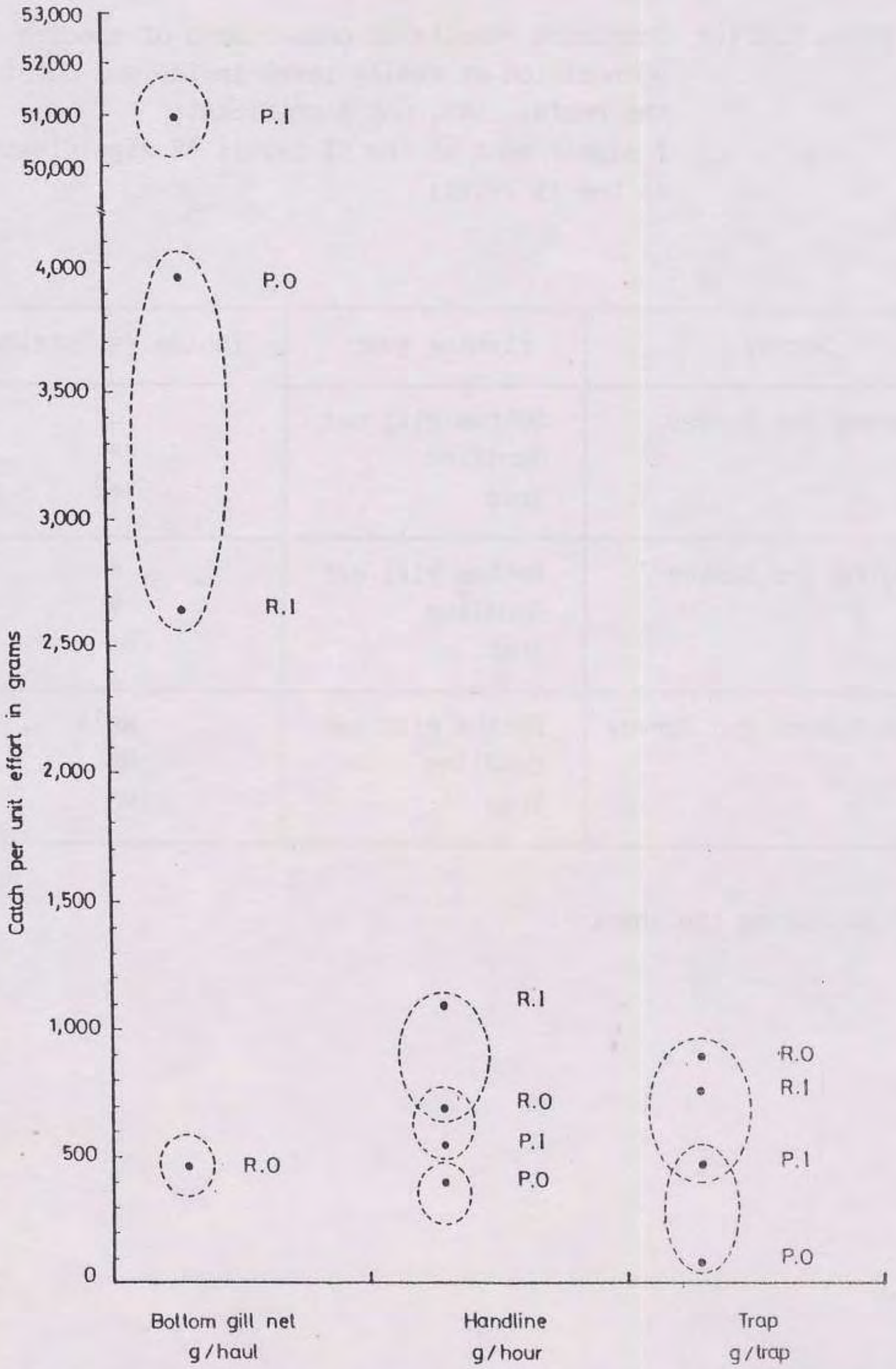


Fig. 7.3.3.1 Mean values (CPUE) of each haul, hour and unit for the three fishing gears off Rayong and Petchaburi

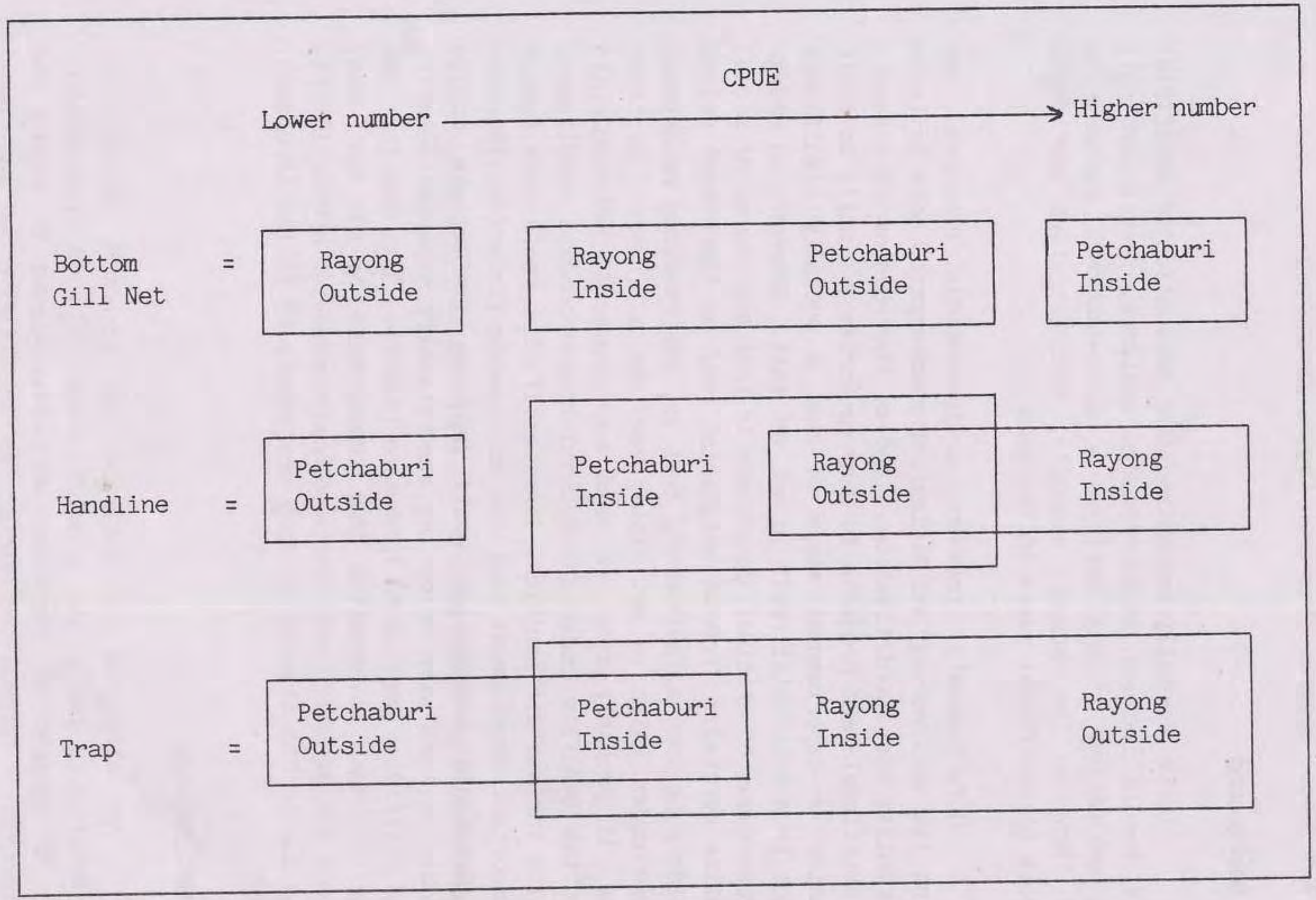


Fig. 7.3.3.2 Grouping of mean values of CPUE for three fishing gears

7.4 Socio-economic Research (by H. Yonesaka)

1. Background

It is generally recognized that evaluation of artificial reefs should include socio-economic analysis, and accordingly this evaluation project employed a socio-economic approach to shed light on the social, economic, administrative and legal aspects of artificial reefs in Thailand.

Unfortunately, however, socio-economic research lags behind its engineering and biological counterparts both in terms of quantity and sophistication. One of the reasons is evident; the artificial reef projects in many countries are still in their infantcy or experimental stage so that a socially significant impact from artificial reefs is not yet felt. However, an emerging consensus of critical importance is that the degree of social benefits derivable from an artificial reef as "hardware" relies considerably upon a "software", that is, the resource management regime under which an artificial reef is utilized. In other words, it probably does not make much sense to calculate its potential benefits under far-fetched socio-economic conditions. Despite various difficulties, since artificial reefs have become an important development tool for small-scale fisheries, increasing available information would help us contemplate socio-economic systems with which the theoretically expected benefits of an artificial reef would have more reality. Yet, for the time being, it must be accepted that researchers do not have many options but to carry out socio-economic research within limitations due to the absence of many precedents to follow (Bohnsack, 1985).

2. Methodology

We attempted to estimate the economic benefits of the artificial reefs and acquire other relevant information. About 60 samples of fishermen were interviewed in Rayong and Petchaburi. Information about the administrative and legal aspects was acquired through personal communication with the national and provincial fishery officers who were directly involved with the artificial reef projects. Additionally, relevant literature, which was scattered in various documents and reports, was reviewed in order to identify the status of these artificial reefs in comparison with other artificial reefs in Thailand.

In the process of conducting this research, we encountered some difficulties stemming from the lack of baseline information, the rather obsolete stage and small size of the artificial reefs and the lack of a well elaborated policy paper. The vague nature of the fishermen's remarks also sometimes left too wide a range for interpretation. However, at the same time, it is also true that some important information reported in the following section was obtainable only through interviews with those fishermen.

3. Findings

This section summarizes some findings which may have important implications on future artificial reefs. Due to the reason described in paragraph (1) below, the discussion is largely based on the research in Rayong, particularly at Ao Makam Pom, a fishing community located in proximity to the artificial reef surveyed.

(1) Construction

As far as the Petchaburi project is concerned, few socially significant benefits are detectable; inadequate arrangements for module construction and installation seem to be responsible for the simply scattered remnants of the artificial reef. Obviously the construction of a physically stable artificial reef is always the first requirement for the projects, though the construction by itself is not synonymous with the fulfillment of a project's objectives. The fact that the Petchaburi artificial reef failed this first requirement and was practically nonexistent was found by our diving team and confirmed by the local fishermen claiming negligible utility of the reef. This presents a clear contrast with the Rayong artificial reef which many fishermen regarded as beneficial.

(2) Distance

The maximum allowable distance between an installation site and a targeted small-scale fishing community appears to be about 10 km. This implies that the best construction site of an artificial reef should be able to be chosen well beyond the 3 km from shore trawl off-limit line.

(3) Combination with Natural Reefs

It was also found that the fishermen utilized the artificial reef as one of several rotation spots the rest of which were in their traditional fishing grounds embracing natural reefs. During a fishing trip, which is normally completed within a day, a fisherman rotates among these spots in search of the better catch of the day. We encountered no fishermen who exclusively or even mostly depend on the artificial reef, although neither the artificial reefs nor the natural reef gained an absolute majority among the local fishermen in terms of their judgement of superiority. This infers that an artificial reef installed near existing fishing grounds is likely to be used more than an isolated artificial reef, unless the isolated reef is large enough to provide several rotation spots.

(4) Gear Group

The quantium of benefits derived by different gear groups was in the descending order of fish trappers, purse-seiners, gill netters and squid trappers. Naturally, different attitudes such as enthusiasm, indifference and unawareness among the fishermen also clearly corresponded to the different degrees of benefit they reported. (see Fig. 7.4.1) Since the group anticipated to gain the most benefit was small-scale fishermen, it was a little surprising that the majority of local purse seiners claimed to have taken much advantage of the artificial reef attracting such small pelagic fish as sardine.

Incidentally, there was a report from another fishing community in Rayong Province that squid trappers, who get the least direct benefit from artificial reefs, regarded natural reef areas as a prime location for setting traps not because of an increment in catch but because their gear escapes destruction by trawlers. Although we do not have evidence to generalize this practice in other communities, this report suggested that artificial reefs could help alleviate the appalling costs to squid trappers of replenishing every month all the traps which vanish because of the trawlers.

(5) Trawler

Despite our expectations of hearing strong objections from small trawlers, against whose intrusion into coastal waters the artificial reefs were set up, their requests to the Government were centered mostly on the clear marking of new artificial reefs in order to prevent the possible hazard of dragging artificial reef modules. It was also found that, no case of politically inspired opposition representing these trawlers' interests has been raised against artificial reef projects. Since small trawl boats, or what are locally called baby trawls, are numerous and not always organized into fishery associations, which the Government notifies of an installation plan for a new artificial reef, a new system for informing those unorganized trawlers must be considered.

(6) Local Initiatives

Initiatives to make self-reliant efforts -- either to install a new reef or to maintain the existing one -- were not prominent among the local fishermen. There were no rules regarding use of the reef, no arrangements to record the catch and no plans to mantain and revamp. As a crucial result, social pressure was not strong enough to countercheck abuses of the reef such as illegal fishing by poisoning which undermine the potential benefits of the artificial reef.

In spite of the fact that the reef was a component of an integrated small-scale fisheries development project assisted by the Canadian Government, a fishermen's group organized during the project period did not substantially function for management of the artificial reef. Neither were the administrative efforts to follow up the project sufficient to induce local initiatives.

(7) Administration

When these artificial reefs were installed, there was no clear-cut administrative policy on the development and management of artificial reefs at the national level. Although these two reefs were not, in a strict sense of the word, an experimental project, the accumulation of experience was still counted upon. Today, as artificial reef experiments transform to full-scale public works, the Artificial Reef Installation Committee which was organized as the administrative core at the national level administers the overall implementation process in accordance with a prescribed project proposal.

4. Cost/Benefit Analysis

We made a preliminary economic cost/benefit examination of the Rayong reef by placing sets of assumptions about the life span of the reef, the number of beneficiary fishermen and the effectiveness of the reef for attracting pelagic fish. Benefits, fishermen as a group could have obtained for the past few years, were estimated at three different levels: the first is the minimal benefit level below which total benefits are very unlikely to fall; the second is the modest benefit level around which actual benefits are supposed to be; lastly, the maximal benefit level indicates the upper most limit of a conceivable range of benefits, thus has a limited implication for careful policy-making compared to the other two levels.

Our stance for estimation is cautious and conservative in interpreting the fishermen's remarks and assessing the effectiveness of the reef, thus our impression is that the actual benefits are more likely to have existed somewhere above the modest level, albeit not far above it, rather than below it. There is another factor why we regard our estimate as conservative; we ignored possible additional sources of benefits such as the reduced operation time and fuel cost and the catch taken, legally or illegally, by fishermen living outside the community. These benefits are not only difficult to assess but are also deemed to have relatively minor effect on the surveyed area, so let us consider these benefits a mere bonus to the total benefits.

Here, in calculating the costs and benefits, we do not adopt a formal approach of economic cost-benefit analysis employing discount rate, shadow price and the like, for we believe it will unnecessarily complicate the discussion in this specific case which is based on an educated interpretation of essentially qualitative data instead of those reasonably quantified from the outset.

(1) Minimal Benefits

The most strict view consisting of the following assumptions is adopted in interpretation of the fishermen's responses and the effectiveness of the reef. Table 7.4.1 shows the results of the calculation; the estimated total benefits from 1983 till 1986 are 600 thousand baht. If ten per cent of the potential benefits from demersal fish is hypothesized to be lost to illegal fishing, the could-be-obtained total benefits are 660 thousand baht.

a. The real productivity-enhancing effect of the reef affects only demersal species and thereby serves only fish trappers and handliners. The reasoning behind this assumption is that, unlike demersal fish, pelagic fish caught around the reef could be caught somewhere else because they are a migratory resource originating in other water and are simply drawn to the reef (Mottet quoted by Bohnsack, 1985). The income earned from pelagic fish, therefore, does not constitute a genuine income generated locally but should be rather considered income transfer from another group of fishermen to the local fishermen.

b. The number of trappers and handliners in Ao Makham Pom totals 15. There actually are more than 15 trappers and handliners (Sungthong, 1988), but the size of the reef is supposed to be too small to accommodate them.

c. The results of our interview with the fishermen reflect productivity of the reef at its peak — the first one year period following the installation in 1982. Since then the productivity has diminished by 25 per cent of the peak productivity each year, and there was no effect in 1987. (The total benefits for the four years are equivalent to the annual benefits multiplied by 2.5).

d. The interviewed fishermen tend to exaggerate the effects of the reef, for they naturally think that our favourable evaluation of the existing reef may lead to another government-sponsored artificial reef project in the vicinity. Their exaggerations make their reports amount to double the real benefits, thus benefits per capita must be discounted by 50 per cent.

(2) Modest Benefits

We believe that this level is nearest of the three to the real benefit level. The total benefits estimated under the following assumptions amount to 1,665 thousand baht of which demersal fish account for 1,440 thousand baht or 86 per cent and pelagic fish for the remaining 14 per cent. The could-be-obtained benefits with no illegal fishing are 1,809 thousand baht in total for five years. (see Fig. 7.4.1)

a. The artificial reef was effective for both demersal fish and, to a limited extent, pelagic fish. The limited contribution to the pelagic fish production is approximately 50 per cent of the benefits reported by the fishermen. Justification for this assumption is that, while it is too liberal to attribute pelagic fish production around the reef solely to the advantages of the reef, the complete disregard of the reef's service is too rigid and similarly unrealistic.

b. The number of trappers and handliners totals 20, and there are five gill-netters and five purse seiners operating occasionally around the artificial reefs.

c. The artificial reef has been productive for five years since 1982 with a diminishing efficiency rate of 20 per cent. (The total benefits are equivalent to the annual benefits multiplied by 3).

d. Here, the fishermen's inclination to exaggeration is again taken into account; the discount rate to the claimed per capita benefits for trappers and hand-liners is 25 per cent instead of 50 per cent as in the minimal level.

(3) Maximal Benefits

This is a benefit level over which the real benefits from the reef have not conceivably been able to reach. The assumptions are bold and optimistic about the effectiveness of the reef. The estimated total benefits are 6,100 thousand baht out of which 4,000 thousand baht or 66 per cent is from demersal fish (see Fig. 7.4.1).

a. The reef is the major contributor for pelagic fish production as well as demersal fish production around the reef. The proportion of the contribution from other factors such as income transfer and seasonal fluctuation of stock level -- that is, the discount rate to the claimed benefits -- accounts for only 25 per cent.

b. The numbers of beneficiary fishermen engaged in the trapping and handlining, the gill-netting and the purse seining are 25, 10 and 10, respectively.

c. The claimed annual benefits indicate the average annual benefits over the past five years rather than those in the reefs heyday. (The total benefits are equivalent to the annual benefits multiplied by 5).

d. The benefits are so straightforwardly claimed without exaggeration that discounting is not necessary.

(4) Costs

The total construction costs of the reef in 1982 and 1983 were reportedly 167 thousand baht (Sungthong, 1988). However, this figure does not appear to include properly the cost of services provided by Government officers and equipment. Tires were also provided at minimal cost. Based on the claimed costs of 167 thousand baht, the unit cost to create one cubic meter of artificial reef was, in our estimation, only 55 baht. In fact, if this unit cost is compared with that of another artificial reef project contracted recently by a private company, the figure is very low.

In order to get more realistic costs for the project, some adjustments are necessary. First, costs of the tire modules must be recalculated in terms of the unit cost of one cubic meter module made of concrete drain pipes, which were actually used at the cost of 50 baht each. As two pieces of the concrete drain pipes can make up one cubic meter, the unit material cost could be 100 baht. Secondly, labour and over-head costs are assumed to be 30 per cent of the cost of materials. Eventually, the total unit cost is calculated to be 130 baht instead of 55 baht and the total costs to be 390 thousand baht instead of the claimed 167 thousand baht.

(5) Comparison of Benefits with Costs

As the graph in the right part of Figure 8.3.1 (P. 145) illustrates, even the minimal level of benefits surpasses the recalculated total costs, which are indicated by a dotted line marked 130 Bht/m^3 in terms of a unit cost rather than of total costs. The benefits at the modest level are about four-fold of the same total costs. If the illegal fishing had been effectively controlled, the total benefits and thereby the total net benefits could have been larger. However, even with periodical illegal fishing, substantial net benefits were realized. In conclusion, we believe that the Rayong artificial reef as an experimental project was quite successful as far as the balance sheet is concerned.

Table 7.4.1 Estimated Actual Benefits from Artificial Reef No.6 off Rayong

	Demersal Fish	Minimal	Modest	Maximal
(1)	Benefit per capita	16	24	32
(2)	No. of Fishermen	15	20	25
(3)	Year Conversion	2.5	3	5
(4)	Sub-total Benefit	600	1,440	4,000
	Pelagic Fish -- Gill net			
(5)	Benefit per capita	0	6	8
(6)	No. of Fishermen		5	10
(7)	Year Conversion		3	5
(8)	Discount Rate		50%	25%
(9)	Sub-total Benefit	0	45	300
	Pelagic Fish -- Purse Seine			
(10)	Benefit per capita	0	24	48
(11)	No. of Fishermen		5	10
(12)	Year Conversion		3	5
(13)	Discount Rate		50%	25%
(14)	Sub-total Benefit	0	180	1,800
(15)	ESTIMATED TOTAL BENEFIT	600	1,665	6,100
(16)	Estimated Loss from Illegal Fishing	60	144	400
(17)	COULD-BE-OBTAINED BENEFIT	660	1,809	6,500

Unit : 1,000 B

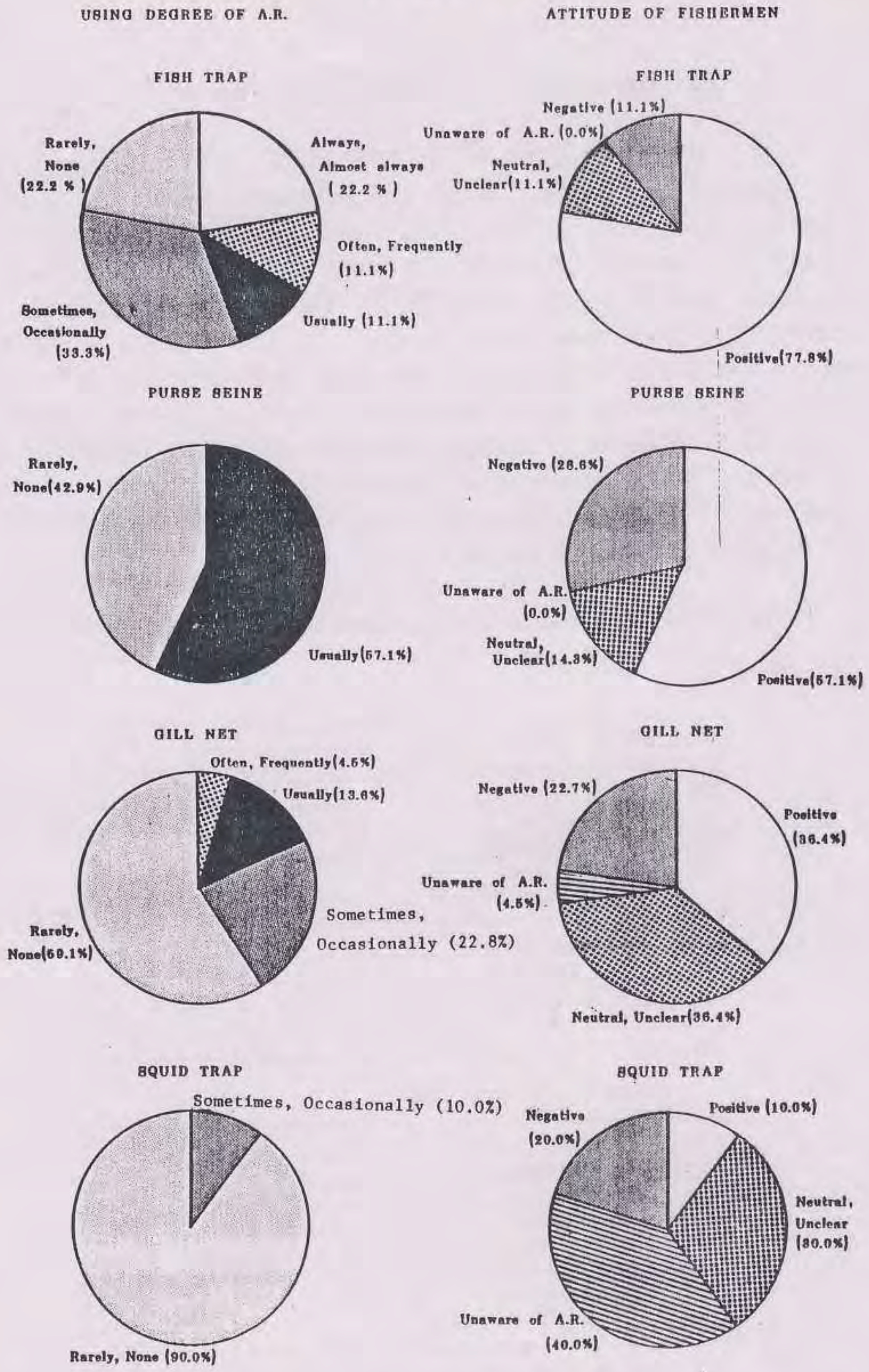


Fig. 7.4.1 The claim of benefits and attitude of fishermen by gear group

8. Recommendations

8.1 Engineering point of view

Shape of module

Many of the required functions of artificial reefs have been described but it is still not clear which is the most important. However, it is possible to say that some effectiveness will be accrued by the simple placement of the structure, in the prevailing current. We, therefore, can consider a pyramid shaped module 2-2.5 m in height composed of 3 circular cross-sectioned legs and whose characteristics remain unchanged irrespective of current direction.

Furthermore, when considering the actual construction of the modules, we concluded that the simpler shape is better. Given these criteria, we devised the pyramid shape. In order to stabilize the modules against the wave action and current, the legs of the module are cylindrical. Since the sea-bed of the Gulf of Thailand is thickly sedimented, we attached a foot-plate to each leg to restrain it against the movement of the sediment due to wave action (see text Fig. 1).

Since, in this survey, we found many tyre modules had broken up due to inadequate connection of their components and given that the installed modules were smaller in size than a natural reef, tyre module connecting material should be greately improved so that larger modules with more durability and stability can be built.

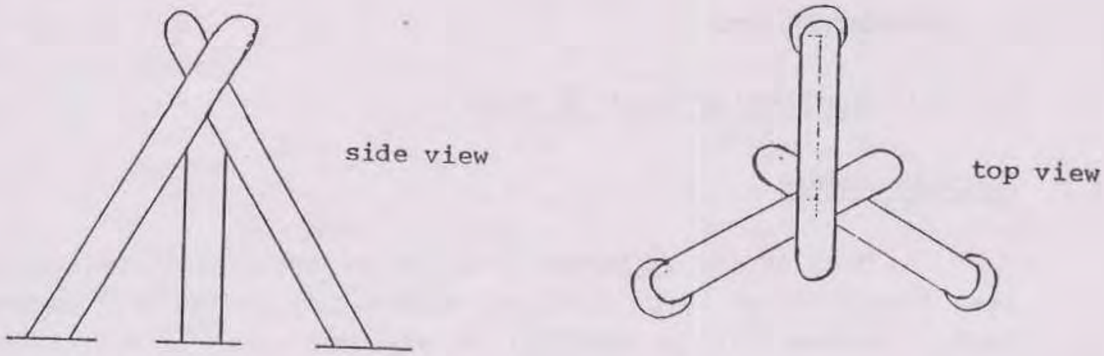


Fig. 8-1. Shape of module

Material used

The pyramid shaped module will be made of concrete and re-inforced with bamboo, which is readily available locally and cheap. The maximum load againsts the module is during the period between pick up from the barge and installation on the sea-bed. To ascertain the strength of bamboo, we carried out an experiment using a tensile strength machine at SEAFDEC/TD. The results of this experiment, shown in Table 8.1.1, indicate that sheathed bamboo has nearly one-half the tensile strength of the steel bars used for re-inforced concrete.

Design

In this section, we calculate the external force which will work against the modules after they are placed on the sea-bed. The modules should be stable and work without either over-turning or sliding. The external forces against the modules are wave action and current speed. The force of wave action is usually represented by gravity waves, which are produced by wind of a frequency between one second and thirty seconds. The properties of waves, i.e. wave height (meters), frequency (seconds), wave length (meters) should be considered for the calculation. To decide these properties, we should adopt proven long-term survey data or predict from the wind data. These data should be collected over a long period. However, since the survey period in this project was too short to obtain reliable data, we did not collect these data.

Specifically, the external force must be considered when placing modules off Rayong. The wave height off Rayong is shown in Table 8.1.2. From these data, we can use 2.9 m for a fifty-year return period, which was calculated by the Asian Institute of Technology (AIT).

Current speed would be 0.39 m per second, which was measured as the maximum speed on 3 Feb. '88 off Petchaburi.

From the wave height, frequency and wave length data, the external force can be calculated as follows:

Wave height:H, Frequency:T, Wave length:L

$$H = 2.9 \text{ m}, \quad T = 3.86\sqrt{H} = 6.6 \text{ sec}, \quad L = 1.56\,T^2 = 68 \text{ m}$$

External force on module can be calculated as follows:

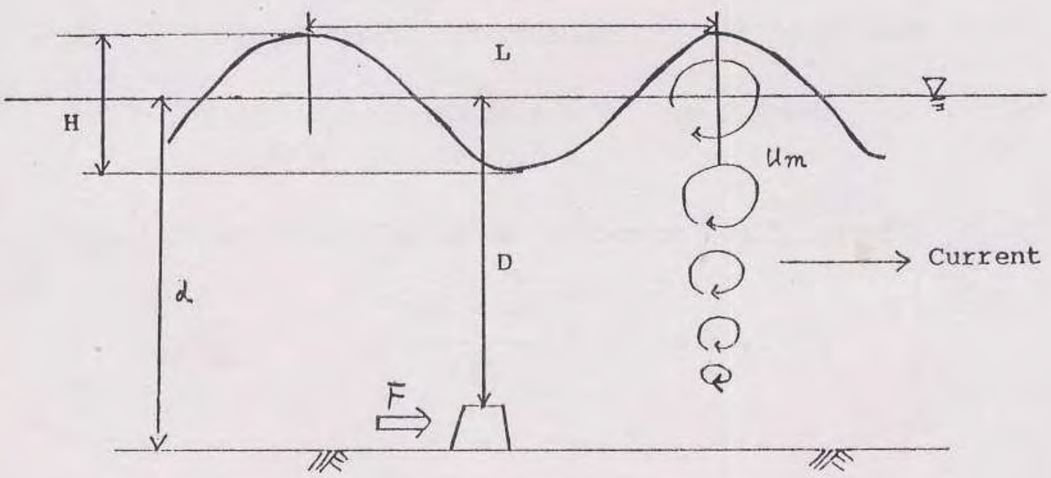
$$F = C_D.A.W_o \qquad = \frac{(Uo + Um)^2}{2g}$$

C_D : drag coefficient (1.0)
A : total shadow area of vertical surfaces perpendicular to the direction of progress of waves (m^2)
W_o : unit volume weight of sea water ($1.03t/m^3$)
g : gravitational acceleration ($9.8\ m/sec^2$)
U_o : velocity of current (m/sec)
U_m : velocity of water particles created by waves

$$U = \frac{\pi H}{T} \cdot \frac{\cosh 2\ D/L}{\sin h\ 2\pi\ h/L}$$

H : wave height (M)
T : wave frequency (cycle/sec)
L : wave length (m)
D : depth from sea surface to the top of module (m)
d : depth from sea surface to sea-bed (m)

External force caused by waves and current:



Resistance to sliding can be calculated as follows:

$$S_1 = 1.2 < \frac{Ww \cdot \mu}{F}$$

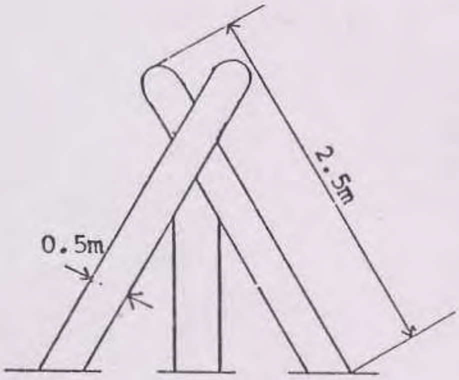
S_1 : optimum slide resistance coefficient
Ww : submerged weight of module (Ww = W-Fo)
μ : coefficient of friction between module and sea-bed (0.6)
W : weight of module
F_o : buoyancy

Resistance to overturning can be calculated as below:

$$S_2 = 1.2 < \frac{Ww \cdot 1A}{F \cdot 1G}$$

S_2 : optimum overturn resistance coefficient
1_G : distance from sea-bed to the center of gravity *1
1_A : distance from side of module to center of figure *2

Specifically, calculations can be carried out using the new shape of module shown in Fig. 8.1 (page 132).



$$W = \left(\frac{0.5}{2}\right)^2 \times 3.14 \times 2.5 \times 2.3 \times 3$$

$$= 3.39 \text{ (t)}$$

$$A = 2.5 \times 0.5 \times 3 = 3.75 \text{ (m}^2\text{)}$$

$$U_m = \frac{3.14 \times 2.9}{6.6} \times \frac{\cos h\frac{2\times3.14\times(15-2.2)}{68}}{\sin h\frac{2\times3.14\times15}{68}}$$

$$= 1.31$$

$$F = 1.0 \times 3.75 \times 1.03 \times \frac{(0.39+1.31)^2}{2 \times 9.8}$$

$$= 0.57$$

$$W_W = \left(\frac{0.5}{2}\right)^2 \times 3.14 \times 2.5 \times 3 \times (2.3-1.03)$$

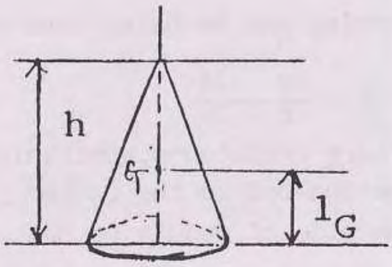
$$= 1.87$$

$$S_1 = 1.2 < \frac{1.87 \times 0.6}{0.57} = 1.97$$

$$S_2 = 1.2 < \frac{1.87 \times 0.625}{0.57 \times 0.625} = 3.28$$

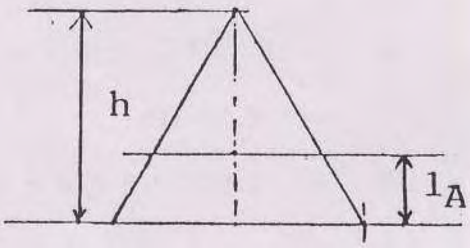
From the results of these calculations, according to "Structure Design Guidelines for Coastal Fishing Ground Improvement and Development Projects; 1984 Edition, Published by the National Association of Coastal Fisheries Promotion and Development in Japanese," it is possible to say that the new shape module is stable when the modules are installed off Rayong Province at a depth of approx. 15 m.

* 1



$$l_G = \frac{h}{4}$$

* 2



$$l_A = \frac{h}{3}$$

Table 8.1.1 Tensile Strength

Number of Bamboo* poles	Tensile strength (kg/cm)	Remarks
1	1,199	has no sheath, without joint
2	1,089	
3	1,330	
4	1,094	
5	1,004	
6	1,229	
7	1,191	
8	1,323	
9	1,410	has sheath
10	1,461	
11	922	has no sheath, with joint
1 steel bar Ø 6 mm	3,000	as used in building construction

(JIS 2-2201-1968, revised 1971)

*

footnote: *Bambusa blumeana*, bamboo-unprocessed, sectioned longitudinally between joints.

Table 8.1.2 Comparison of wave data off Rayong

Source	Type of Data	Water Depth	Significant wave heights, H_s(metres)	Remarks
1. JICA (Ref. 1)	Measured	5 m CD	2.3	Maximum H_s recorded during August - September 1982
2. Nippon Koei	Measured	5.5 m CD		Maximum H_s recorded during 1984-1985
3. Geomex survey (Ref. 2)	Measured	6.5 m CD	1.7	Maximum H_s recorded during September 1982
4. JICA (Ref. 1)	Wind hindcast	 Deep water 5 m CD	Return Period (years): 10 50 100 3.1 3.7 3.9 3.0 3.5 3.7	Hindcass using scaled Sattahip wind data for period 1964-1981 and the SMB method. Refraction and shoaling then applied to obtain shallow water values
5. AIT (Ref. 3)	Wind hindcast	6 m CD	Return Period (years): 1 10 50 100 2.4 2.7 2.9 3.1	Winds scaled to fit measured wave data and hindcast undertaken using Pierson-Moskowitz spectral parameterisation
6. DHI (Ref. 4)	Wind hindcast	Deep water	4.5 5.5	1 in 100 year value for sea area 11°- 12° N 1 in 100 year value for sea area 9°- 10° N
7. Maunsell (Ref. 5)	Wind hindcast	Deep water	2.9	Maximum sea state during Typhoon "Voe"
8. Halcrow	Wind hindcast	Deep water	Return Period (years): 10 50 100 3.3 4.6 5.2	SMB hindcast of tropical cyclones using Sattahip wind data and a correction factor of 2 x (Ref. 3)
9. NMIMET	VOS data	Deep water	Return Period (years): 1 10 50 100 4.0 4.8 5.3 5.5 2.8 3.5 4.0 4.2 3.3 4.1 4.5 4.7 3.8 4.6 5.1 5.3	Data for all directions " direction sector 136°- 180° " direction sector 181°- 225° " direction sector 226°- 270°
10. Halcrow	Refraction Analysis	Nearshore 18 m CD 10 m CD	Return Period (years): 1 10 50 100 2.9 3.5 3.8 3.9 2.5 3.0 3.4 3.6	Applied results from refraction and shoaling model to NMIMET results by direction (values given are the largest significant wave heights considering all incident directions)

Source : Preliminary Design Report of Map Ta Phut Port Project 1985

8.2 Biological Point of View

We made a recommendation on the basis of background ideas from the view point of biological research. We cannot expect a rapid increase of resources by installing artificial reefs similar in scale to Unit 6 off Rayong. But, we confirmed that the artificial reefs off Rayong acted positively in creating new fish communities. Therefore, it will be more efficient to catch higher priced target species in these areas, since a small catch of expensive fish shows a greater benefit than a larger quantity of cheaper ones. This is one of the reasons for the installation of the artificial reefs. Therefore, a recommendation was made as follows:

"In considering the type of modules to be installed at moderate scale artificial reefs, we should select or create modules which are most suitable with regard to the life history of selected higher priced fish species group(s) at the planned site, based on existing information and further research for ecology".

Briefly, the procedure for implementing this recommendation is as follows:

1. Select the target species group(s) at the planned site, which are considered most important.

2. Examine the life history period expected to be influenced by the reefs; providing habitats for adult fishes, nursery grounds for juveniles, and so on.

3. Decide the target species group(s)' important period in it's life cycle which will be influenced by the installation of artificial reefs.

4. Plan the selection or creation of modules expected to work efficiently for target species group(s).

8.3 Socio-Economic Point of View

Based on the findings of the socio-economic survey and subsequent analysis, the Team recommends some administrative action and urges consolidation of future artificial reef development policy. While the former is rather urgent but could be addressed technically, the latter requires careful assessment of the past and present projects and, only in the long run, could it be incorporated into the administrative framework.

(1) Recommendations for immediate action

a. Judging from past experience, attaining a seven-year life span for an artificial reef is a feasible technical goal for the near future although a recent project proposal prepared by the Department of Fisheries expects a 10-year life span. Table 8-3-1 and Figure 8-3-1 illustrate possible increments to the total benefits with a hypothetical artificial reef whose size and location are similar to the Rayong artificial reef but whose life span is at least seven years. Let us focus on the modest level of potential benefits which are estimated to increase from that of the actual benefits (Table 7.4.1) by more than 20 per cent to 2,137 thousand baht. As a result, the unit cost is also allowed to rise to about 700 baht. However, it is clear that a unit cost of 350 baht is more desirable because at this unit cost the total cost is at the breakeven point with even the minimal benefits. As unique module designs are developed exclusively for artificial reefs, and less ordinary materials besides used tyres and concrete drain pipes for sewers are utilized, the unit cost will naturally soar. Therefore, it is recommended that administrators pay due attention to the cost element and make concerted efforts to contain the unit cost below 700 baht, even though the 350 baht level is impossible to maintain. There are many ways to attain cheaper unit costs; for instance, the economy of scale through standardization of module design, search for an alternative material, and voluntary labour of would-be beneficiary fishermen.

In summary, the result of the preliminary cost/economic examination implies, under similar conditions to the reef in Rayong, an economically feasible artificial reef project would require the following conditions:

1) The modules and reef structures should have a life span of at least 7 years.

2) The manufacturing and transportation costs should be below 700 baht per one cubic meter.

3) To a lesser extent, effective control of the illegal fishing should be ensured.

b. Another issue to which administrators should address themselves without procrastination is the preparation of the national artificial reef policy paper, which describes objectives, practical goals, standard administrative procedure and issues yet to be addressed. One example is the question of, what is the most important objective achievable with artificial reefs -- the prevention of trawlers incursion into coastal water or resource-enhancement for small-scale fishermen. These two objectives share much common ground but are not necessarily identical. In fact, there is a trade-off relationship between the two particularly in terms of the pattern of reef deployment. Instead of listing the possible advantages of artificial reefs, careful consideration for prioritizing the national objectives is required now.

c. Another area to which considerable administrative effort should be directed is social awareness of fishery resources conservation. Our honest impression is that not only the public, but, also the small-scale fishermen, have little knowledge about artificial reefs. The dissemination of the concept of artificial reefs among fishermen and the popularization of the words "artificial reefs" among the general public in the context of the critical condition of marine resources in national waters should be promoted immediately.

(2) Recommendations for the improvement of Future Projects

a. Artificial reef projects in Thailand have been implemented as pure public works and have put little emphasis on local participation. Local fishermen's involvement in planning, construction and safeguards are so minimal that they tend to regard the projects as a free meal. Describing the management situation of an artificial reef in Nakorn Sri Thammarat, Sinanuwong wrote:

"The small-scale fishermen in the three villages didn't feel that the artificial reef belonged to them and did not show any awareness that the government had built it for their benefit and that they ought to make use of it. They had no feeling of possession and didn't feel that it was their responsibility to look after the artificial reef." (1988).

The development projects given by the Government regardless of the local population's commitment tend to have negative implications for the creation of a spirit of self-reliance, which is an indispensable component for self-generated, sustainable development. In the process of implementing artificial reefs, the Philippine Government tries to induce local participation as much as possible. Local participation in artificial reef projects can be encouraged in various ways such as involvement in planning, financial contributions, provision of labour, vigilance against abuse, and cooperation with administrators in collecting catch data. Although there is no doubt that the precise formula for local participation should be determined depending on the community-specific conditions and be improved through the trial and error process, what is crucial in fostering local participation in the early stages is the "political will" of the Government as well as the practical visions of project managers and local leaders. It is hoped that future artificial reef projects will help local fishermen establish confidence in self-reliance rather than deepen the sense of dependency.

b. An issue associated with the local participation is whether to grant local fishermen territorial use rights of fishery (TURFs) with regard to artificial reefs. Frequently, strong doubts have been expressed toward the wisdom of imposing nation-wide, institutionalized TURFs in developing countries. However, artificial reefs provide an alternative approach to TURFs, which is what we would call the "micro" approach. In contrast to the conventional "macro" approach which attempts to realize TURFs by imposing the decision in the capital city, the "micro" approach nourishes the possibility of a new small-scale, piece-meal TURF, wherever one has a chance. The ramification is that artificial reefs provide an ideal setting for these small TURFs being introduced around them, and when policy is well coordinated with the local participation aspect, it may develop to be the prelude to more management-oriented coastal fisheries.

c. Finally, we would like to suggest that the utility of legislation of a "National Artificial Reef Development Act" be considered. Such legislation would clarify various legal complexities regarding the artificial reefs. Examples are property rights, concessions, user conflicts and liabilities. Admittedly, the adoption of an elaborated policy paper is more urgent and probably sufficient for the time being. However, the legislation of such as Act should be considered a means to underpin the sound development of artificial reef projects in the long run.

Table 8.3.1 Estimated Potential Benefit from a Hypothetical Artificial Reef whose Size is the same as A.R. No.6 off Rayong but whose life span is seven years.

	Demersal Fish	Minimal	Modest	Maximal
(1)	Benefit per capita	16	24	32
(2)	No. of Fishermen	15	20	25
(3)	Year Conversion	3.85	3.85	7
(4)	Sub-total Benefit	924	1,848	5,600
	Pelagic Fish -- Gill net			
(5)	Benefit per capita	0	6	8
(6)	No. of Fishermen		5	10
(7)	Year Conversion		3.85	7
(8)	Discount Rate		50%	25%
(9)	Sub-total Benefit	0	58	420
	Pelagic Fish -- Purse Seine			
(10)	Benefit per capita	0	24	48
(11)	No. of Fishermen		5	10
(12)	Year Conversion		3.85	7
(13)	Discount Rate		50%	25%
(14)	Sub-total Benefit	0	231	2,520
(15)	ESTIMATED TOTAL BENEFIT	924	2,137	8,540
(16)	Estimated Loss from Illegal Fishing	92	185	560
(17)	COULD-BE-OBTAINED BENEFIT	1,016	2,322	9,100

Unit : 1,000 B

Hypothetical A.R. of the same size as A.R. No.6 with a 7-year life span

A.R. No.6 off Rayong

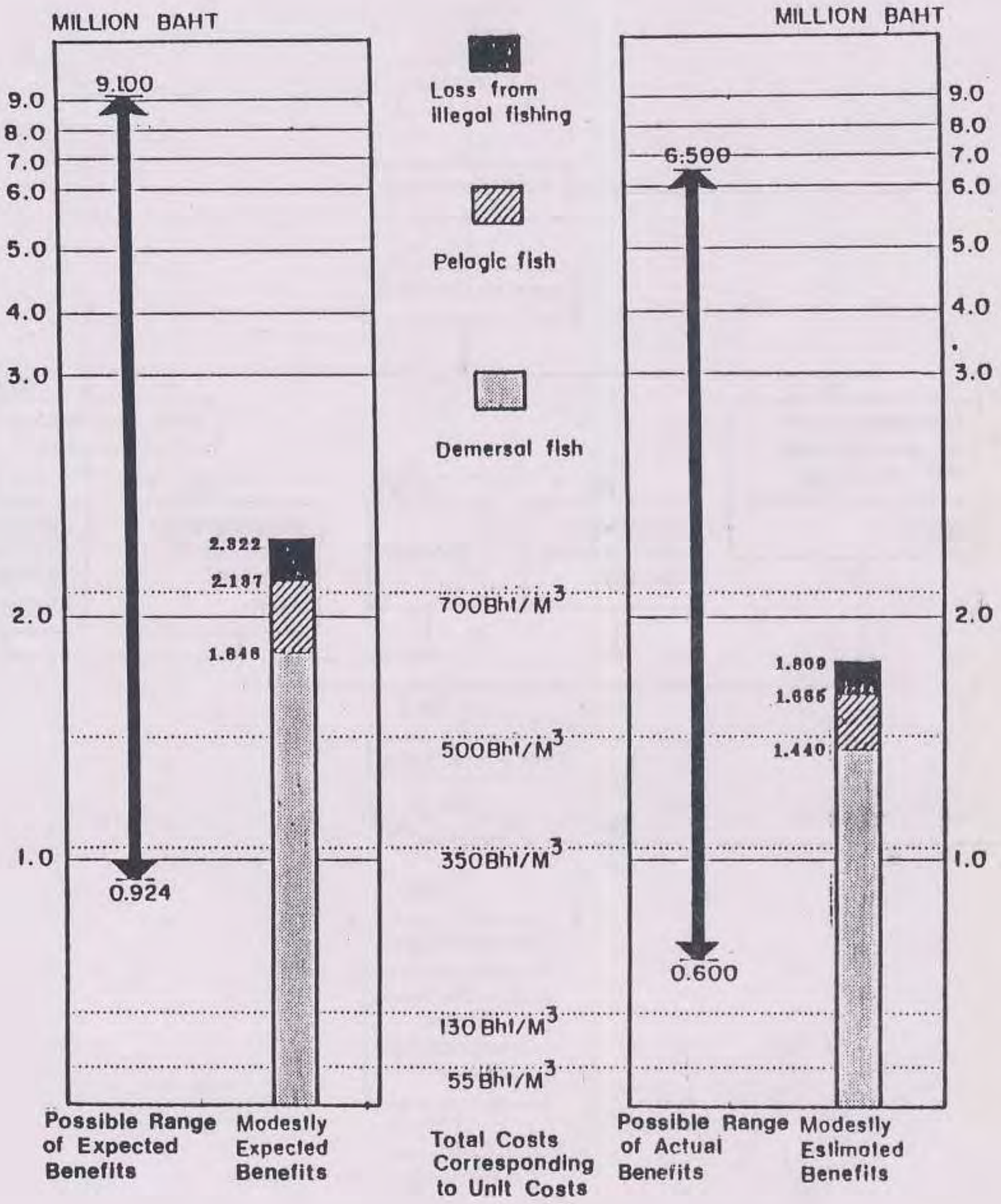
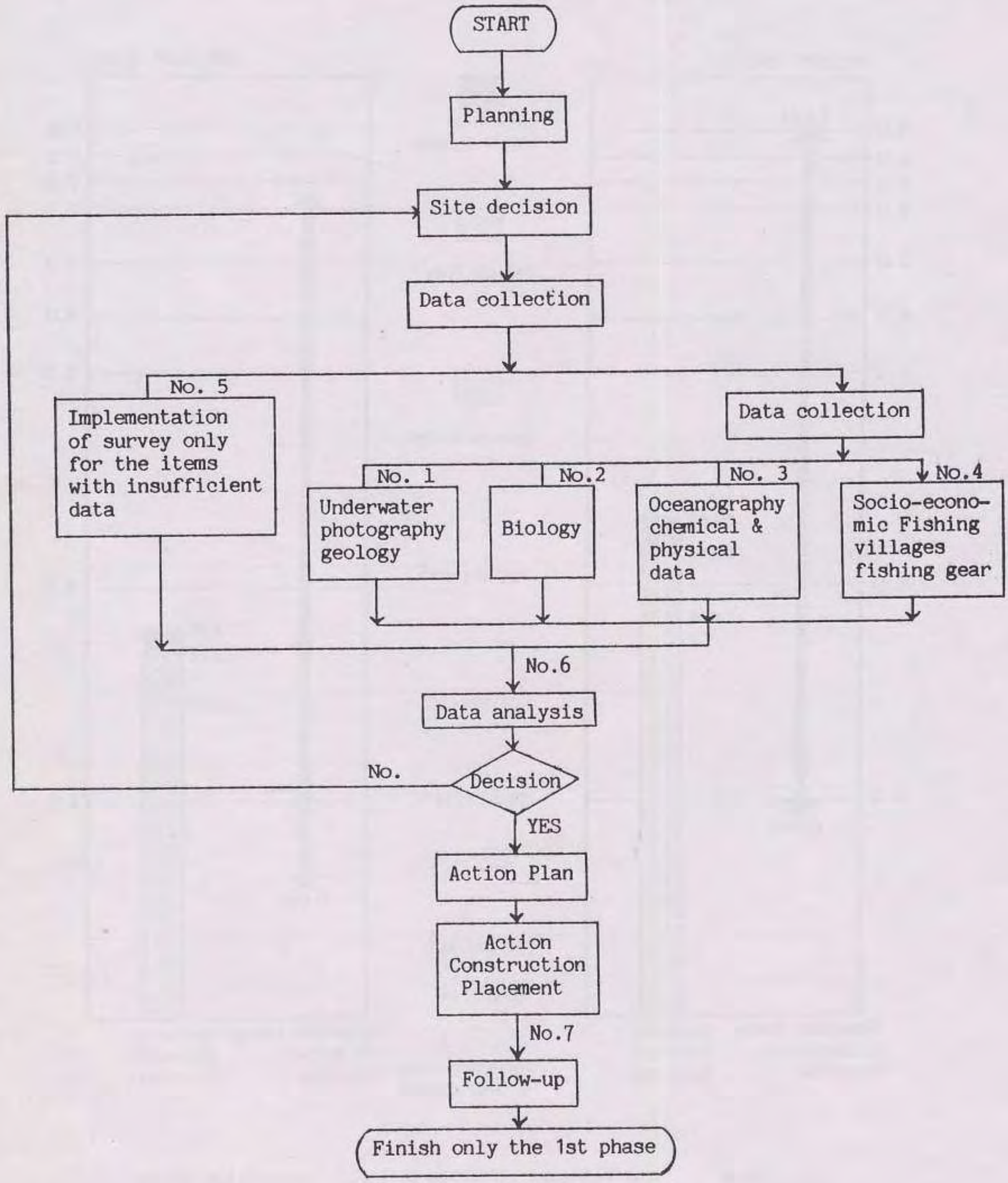


Fig. 8.3.1 The ranges of the actual benefits from A.R. No. 6 off Rayong and the possible benefits from an artificial reef with a 7-year life span

8.4 Flowchart of artificial reef work



Flow chart of Artificial Reef Work (1st phase)

The flowchart shows the procedure for artificial reef work. The details of each block from No.1 to No.7 are as follows:

Note 1: Underwater topography, geography

*Generally, the site will be selected based on the underwater topographic features, which are shown by the contour lines on the chart. For instance, a suitable site will depend on the sea-bed gradient, as depicted by the contour lines.

*As to natural reefs, their positions and shapes must be accurately charted.

*The bottom quality should be analyzed after sampling.

Note 2: Biology

*The target species should be chosen (usually, from commercial species).

*The movement and/or distribution of target species throughout their phasic development should be made clear.

*Their feeding habits and predator-prey interaction should be established (stomach contents should be studied).

*The survey of prey should be undertaken (collect plankton and benthos).

*The ecological characteristics of the target species should be observed (diving observation and/or biotelemeter).

*The resources estimation should be made to evaluate the possible quantity of catch (statistical analysis, tagging, sampling catch).

Note 3: Oceanography

*Current speed and direction should be measured. This should be done throughout the year (dry, monsoon and winter seasons). The period of measurement should be at least fifteen days, as a standard oceanographical measurement.

*As to wave height, etc. refer to 8-1 (design).

*Temperature and salinity should be measured at the same time as the current.

*As for chemical analysis, nutrients (phosphate and nitrogen) should be measured.

Note 4: Socio-economics

*The next items will be collected to elucidate the fishery situation at the site.

- o Number of fishermen around the site
- o The kinds of fishing gear used
- o Major fishery production by species, both in quantity and value
- o Cost of fishery
- o Fishing ground usage
- o Community organization
- o Illegal fishing

*The management of fishing grounds (after installation) should be considered along with artificial reefs, in order to insure their effectiveness.

Note 5: Implementation of survey

If any data are lacking and/or insufficient, a survey should be carried out for only the corresponding items. The existing data should be collated. Fishermen near the site should be interviewed, so as to better understand the effectiveness and validity of these items.

Note 6: Data analysis

All data collected (from No.1 to No.5) should be analyzed individually, according to their methodology. After that, the characteristics of the site will be more comprehensible. This will lead to a decision whether to proceed or not. The results will further influence the required investment to acheive the projected efficiency of the site.

Note 7: Follow-up

At least one year after installation of the artificial reefs, the survey should repeat items No.1 to No.4. Depending on the results, the plan could be subject to restudy and/or re-evaluation.

Furthermore, from the first step of planning, the local fishermen should be involved to make the most of their experience. The effectiveness of the work should be cross-checked with parallel sites, which will increase the overall effectiveness of the individual projects.

9. Conclusion

This is the first time in Thailand when a repeat survey has been carried out on artificial reefs installed experimentally along the coast line. The interval between each survey could not be fixed equally due to the limitations of the survey period. Thus, it was difficult to evaluate the ecological characteristics of major fish species, which should be the main subject of this project.

Considering these reservations, this report is, in its present form, an inadequate evaluation of the project, which should normally make a comparison to a former survey of an artificial reef installation.

Nevertheless, the team would be pleased if this report were used as a reference for other projects, not only in Thailand but also in other Southeast Asian countries which are going to push forward with artificial reefs.

Before closing, the team leader wishes to express his appreciation for the cooperation and assistance rendered to him during this work. The team leader is most grateful, particulary to the team members and the director of the Eastern Marine Fisheries Development Center, without whose assistance it would have been impossible to complete this work.

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Appendix

Table 4.1 Number of Specimens and Occurrence Frequency Obtained from Inside the Reefs by Bottom Gill Net during the First Survey off Rayong

Rayong, 1st Survey Bottom Gill Net	Inside the Reefs			
	no. of specimens		%	Occurrence frequency
	Family	Species		
Orectolobidae	3		11.5	0.60
Chiloscyllium punctatum		3	11.5	0.60
Dasyatidae	5		19.2	0.60
Taeniura lymma		5	19.2	0.60
Muraenidae	2		7.7	0.20
Gymnothorax pictus		2	7.7	0.20
Holocentridae	5		19.2	0.60
Myripristic hexagonus		5	19.2	0.60
Serranidae	2		7.7	0.40
Cephalopholis boenack		2	7.7	0.40
Latidae	1		3.8	0.20
Psammoperca waigiensis		1	3.8	0.20
Nemipteridae	1		3.8	0.20
Scolopsis ciliatus		1	3.8	0.20
Leiognathidae	1		3.8	0.20
Secutor indicius		1	3.8	0.20
Chaetodontidae	1		3.8	0.20
Chelmo rostratus		1	3.8	0.20
Labridae	1		3.8	0.20
Choerodon schoenleinii		1	3.8	0.20
Scorpaenidae	1		3.8	0.20
Scorpaenopsis cirrhosa		1	3.8	0.20
Ostraciontidae	3		11.5	0.40
Rhynchostracion nasus		3	11.5	0.40
Total	26	26	100.0	5 hauls

Table 4.2 Number of Specimens and Occurrence Frequency Obtained from Inside the Reefs by Handline during the First Survey off Rayong

Rayong, 1st Survey Handline	Inside the Reefs			
	no. of specimens		%	Occurrence frequency
	Family	Species		
Muraenidae	1		1.9	0.14
Gymnothorax pictus		1	1.9	0.14
Serranidae	5		9.6	0.43
Epinephelus bleekeri		2	3.8	0.29
Cephalopholis pachycentron		1	1.9	0.14
Epinephelus magachir		1	1.9	0.14
Cephalopholis boenack		1	1.9	0.14
Lutjanidae	23		44.2	0.86
Lutjanus vitta		23	44.2	0.86
Nemipteridae	9		17.3	0.71
Nemipterus tolu		2	3.8	0.29
Scolopsis ciliatus		6	11.5	0.57
Scolopsis vosmeri		1	1.9	0.14
Pomadasyidae	1		1.9	0.14
Plectorhynchus pictus		1	1.9	0.14
Lethrinidae	12		23.1	0.71
Lethrinus lentjan		12	23.1	0.71
Labridae	1		1.9	0.14
Halichoeres nigrescens		1	1.9	0.14
Total	52	52	100.0	7 times

Table 4.3 Number of Specimens and Occurrence Frequency Obtained from Inside the Reefs by Trap during the First Survey off Rayong

Rayong, 1st Survey Trap	Inside the Reefs			
	no. of specimens		%	Occurrence frequency
	Family	Species		
Muraenidae	1		2.6	0.13
Gymnothorax pictus		1	2.6	0.13
Holocentridae	6		15.4	0.13
Myripristis hexagonus		6	15.4	0.13
Latidae	2		5.1	0.13
Psammoperca waigiensis		2	5.1	0.13
Apogonidae	2		5.1	0.13
Archamia lineolata		2	5.1	0.13
Lutjanidae	9		23.1	0.50
Lutjanus vitta		9	23.1	0.50
Nemipteridae	1		2.6	0.13
Scolopsis vosmeri		1	2.6	0.13
Mullidae	7		17.9	0.13
Upeneus tragula		7	17.9	0.13
Chaetodontidae	9		23.1	0.25
Chelmo rostratus		9	23.1	0.25
Siganidae	1		2.6	0.13
Siganus oramin		1	2.6	0.13
Total	39	39	100.0	8 traps

Table 4.4 Number of Specimens and Occurrence Frequency Obtained from Both Inside and Outside the Reefs by Bottom Gill Net during the Second Survey off Rayong

Rayong, 2nd Survey Bottom Gill Net	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Orectolobidae	2		14.3	0.67	0		-	-
Chiloscyllium punctatum		2	14.3	0.67		0	-	-
Dasyatidae	2		14.3	0.33	0		-	-
Taeniura lymma		2	14.3	0.33		0	-	-
Holocentridae	2		14.3	0.67	0		-	-
Sargocentron rubrum		2	14.3	0.67		0	-	-
Carangidae	1		7.1	0.33	0		-	-
Selaroides leptolepis		1	7.1	0.33		0	-	-
Pomadasyidae	2		14.3	0.67	0		-	-
Plectorhynchus pictus		2	14.3	0.67		0	-	-
Siganidae	1		7.1	0.33	0		-	-
Siganus javus		1	7.1	0.33		0	-	-
Aluteridae	4		28.6	0.67	0		-	-
Aluterus monoceros		4	28.6	0.67		0	-	-
Total	14	14	100.0	3 hauls	0	0	-	3 hauls

Table 4.5 Number of Specimens and Occurrence Frequency Obtained from Both Inside and Outside the Reefs by Handline during the Second Survey off Rayong

Rayong, 2nd Survey Handline	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Serranidae	2		3.3	0.50	-		-	-
Epinephelus megachir		1	1.7	0.25		-	-	-
Epinephelus bleekeri		1	1.7	0.25		-	-	-
Lutjanidae	38		63.3	1.00	-		-	-
Lutjanus vitta		38	63.3	1.00		-	-	-
Nemipteridae	-		-	-	5		50.0	1.00
Nemipterus hexodon		-	-	-		5	50.0	1.00
Pentapodidae	-		-	-	2		20.0	1.00
Pentapodus setosus		-	-	-		2	20.0	1.00
Theraponidae	-		-	-	3		30.0	1.00
Therapon jarbua		-	-	-		3	30.0	1.00
Lethrinidae	20		33.3	0.75	-		-	-
Lethrinus lentjan		20	33.3	0.75		-	-	-
Total	60	60	100.0	4 times	10	10	100.0	1 time

Table 4.6 Number of Specimens and Occurrence Frequency Obtained from Both Inside and Outside the Reefs by Trap during the Second Survey off Rayong

Rayong, 2nd Survey Trap	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Muraenidae	2		1.2	0.25	3		13.0	0.25
Gymnothorax pictus		2	1.2	0.25		3	13.0	0.25
Holocentridae	1		0.6	0.25	-		-	-
Sargocentron rubrum		1	0.6	0.25		-	-	-
Serranidae	-		-	-	1		4.3	0.25
Epinephelus bleekeri		-	-	-		1	4.3	0.25
Lutjanidae	129		77.7	0.25	3		13.0	0.25
Lutjanus vitta		129	77.7	0.25		3	13.0	0.25
Nemipteridae	-		-	-	5		21.7	0.75
Scolopsis temporalis		-	-	-		5	21.7	0.75
Pentapodidae	-		-	-	8		34.8	0.75
Pentapodus setosus		-	-	-		8	34.8	0.75
Pomadasyidae	-		-	-	1		4.3	0.25
Plectorhynchus pictus		-	-	-		1	4.3	0.25
Siganidae	34		20.5	0.50	-		-	-
Siganus javus		34	20.5	0.50		-	-	-
Aluteridae	-		-	-	2		8.7	0.50
Aluterus monoceros		-	-	-		2	8.7	0.50
Total	166	166	100.0	4 traps	23	23	100.0	4 traps

Table 4.7 Number of Specimens and Occurrence Frequency Obtained from Both Inside and Outside the Reefs by Bottom Gill Net during the Third Survey off Rayong

Rayong, 3rd Survey Bottom Gill Net	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Dasyatidae	7		35.0	0.67	3		25.0	0.67
Taeniura lymma		7	35.0	0.67		-	-	-
Dasyatis sp.						2	16.7	0.33
Dasyatis imbricatus						1	8.3	0.33
Holocentridae	2		10.0	0.67	-		-	-
Sargocentron rubrum		2	10.0	0.67		-	-	-
Carangidae	1		5.0	0.33	7		58.3	0.67
Caranx macrurus		1	5.0	0.33		7	58.3	0.67
Lutjanidae	2		10.0	0.67	-		-	-
Lutjanus lineolatus		2	10.0	0.67		-	-	-
Nemipteridae	1		5.0	0.33	1		8.3	0.33
Scolopsis cancellatus		1	5.0	0.33		1	8.3	0.33
Pomadasyidae	4		20.0	0.67	-		-	-
Plectorhynchus pictus		4	20.0	0.67		-	-	-
Siganidae	1		5.0	0.33	-		-	-
Siganus oramin		1	5.0	0.33		-	-	-
Platycephalidae	-		-	-	1		8.3	0.33
Platycephalus indicus		-	-	-		1	8.3	0.33
Bothidae	1		5.0	0.33	-		-	-
Pseudorhombus elevatus		1	5.0	0.33		-	-	-
Ostraciontidae	1		5.0	0.33	-		-	-
Rhynchostracion nasus		1	5.0	0.33		-	-	-
Total	20	20	100.0	3 hauls	12	12	100.0	3 hauls

Table 4.8 Number of Specimens and Occurrence Frequency Obtained from Both Inside and Outside the Reefs by Handline during the Third Survey off Rayong

Rayong, 3rd Survey Handline	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Holocentridae	1		0.7	0.11	-		-	-
Sargocentron rubrum		1	0.7	0.11		-	-	-
Serranidae	6		4.3	0.55	-		-	-
Cephalopholis boenack		3	2.2	0.22		-	-	-
Epinephelus bleekeri		3	2.2	0.33		-	-	-
Lutjanidae	91		65.5	1.00	-		-	-
Lutjanus vitta		62	44.6	0.89		-	-	-
Lutjanus lineolatus		26	18.7	0.33		-	-	-
Lutjanus russelli		3	2.2	0.22		-	-	-
Nemipteridae	12		8.6	0.55	4		26.7	1.00
Nemipterus hexodon		2	1.4	0.22		4	26.7	1.00
Scolopsis ciliatus		4	2.9	0.22		-	-	-
Scolopsis dubiosus		4	2.9	0.22		-	-	-
Scolopsis temporalis		2	1.4	0.11		-	-	-
Pentapodidae	2		1.4	0.11	8		53.3	0.50
Pentapodus setosus		2	1.4	0.11		8	53.3	0.50
Pomadasyidae	1		0.7	0.11	-		-	-
Plectorhynchus pictus		1	0.7	0.11		-	-	-
Lethrinidae	26		18.7	1.00	-		-	-
Lethrinus lentjan		26	18.7	1.00		-	-	-
Theraponidae	-		-	-	3		20.0	1.00
Therapon jarbua		-	-	-		3	20.0	1.00
Total	139	139	100.0	9 times	15	15	100.0	2 times

Table 4.9 Number of Specimens and Occurrence Frequency Obtained from Both Inside and Outside the Reefs by Trap during the Third Survey off Rayong

Rayong, 3rd Survey Trap	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Dasyatidae	1		10.0	0.25	-		-	-
Taeniura lymma		1	10.0	0.25		-	-	-
Muraenidae	1		10.0	0.25	3		3.8	0.50
Gymnothorax pictus		1	10.0	0.25		3	3.8	0.50
Holocentridae	2		20.0	0.25	-		-	-
Sargocentron rubrum		2	20.0	0.25			-	-
Apogonidae	-		-	-	63		78.8	0.50
Archamia lineolata		-	-	-		63	78.8	0.50
Lutjanidae	2		20.0	0.50	-		-	-
Lutjanus vitta		1	10.0	0.25		-	-	-
Lutjanus lineolatus		1	10.0	0.25		-	-	-
Nemipteridae	-		-	-	7		8.8	0.50
Scolopsis cancellatus		-	-	-		5	6.3	0.25
Scolopsis temporalis		-	-	-		2	2.5	0.25
Mullidae	-		-	-	2		2.5	0.50
Upeneus tragula		-	-	-		2	2.5	0.50
Siganidae	-		-	-	2		2.5	0.50
Siganus oramin		-	-	-		2	2.5	0.50
Aluteridae	-		-	-	3		3.8	0.50
Monacanthus chinensis		-	-	-		3	3.8	0.50
Ostraciontidae	4		40.0	0.50	-		-	-
Ostracion tuberculatus		4	40.0	0.50		-	-	-
Total	10	10	100.0	4 traps	80	80	100.0	4 traps

Table 4.10 Number of Specimens and Occurrence Frequency Obtained from Inside the Reefs by Bottom Gill Net during the First Survey off Petchaburi

Petchaburi, 1st Survey Bottom Gill Net	Inside the Reefs			
	no. of specimens		%	Occurrence frequency
	Family	Species		
Orectolobidae	135		90.0	1.00
Chiloscyllium punctatum		32	21.3	1.00
Chiloscyllium griseum		103	68.7	1.00
Dasyatidae	6		4.0	1.00
Taeniura lymma		6	4.0	1.00
Serranidae	3		2.0	0.50
Epinephelus tauvina		3	2.0	0.50
Carrangidae	1		0.67	0.50
Atule djeddaba		1	0.67	0.50
Lutjanidae	1		0.67	0.50
Lutjanus russelli		1	0.67	0.50
Nemipteridae	1		0.67	0.50
Scolopsis ciliatus		1	0.67	0.50
Pomadasyidae	1		0.67	0.50
Plectorhynchus pictus		1	0.67	0.50
Sciaenidae	2		1.3	0.50
Johnius belengerii		2	1.3	0.50
Total	150	150	100.0	2 hauls

Table 4.11 Number of Specimens and Occurrence Frequency Obtained from Inside the Reefs by Handline during the First Survey off Petchaburi

Petchaburi, 1st Survey Handline	Inside the Reefs			
	no. of specimens		%	Occurrence frequency
	Family	Species		
Sillaginidae	6		31.6	0.33
Sillago maculata		1	5.3	0.33
Sillago sihama		5	26.3	0.33
Carangidae	1		5.3	0.33
Atule mate		1	5.3	0.33
Lutjanidae	9		47.4	1.00
Lutjanus russelli		6	31.6	1.00
Lutjanus vitta		3	15.8	0.67
Nemipteridae	2		10.5	0.67
Scolopsis ciliatus		2	10.5	0.67
Scataphagidae	1		5.3	0.33
Scataphagus argus		1	5.3	0.33
Total	19	19	100.0	3 times

Table 4.12 Number of Specimens and Occurrence Frequency Obtained from Inside the Reefs by Trap during the First Survey off Petchaburi

Petchaburi, 1st Survey Trap	Inside the Reefs			
	no. of specimens		%	Occurrence frequency
	Family	Species		
Orectolobidae	1		5.3	0.17
Chiloscyllium griseum		1	5.3	0.17
Plotosidae	1		5.3	0.17
Plotosus canius		1	5.3	0.17
Lutjanidae	4		21.1	0.67
Lutjanus russelli		4	21.1	0.67
Sciaenidae	10		52.6	0.67
Johnius belengerii		10	52.6	0.67
Aluteridae	2		10.5	0.33
Monacanthus chinensis		2	10.5	0.33
Batrachoididae	1		5.3	0.17
Halophryne trispinosus		1	5.3	0.17
Total	19	19	100.0	6 traps

Table 4.13 Number of Specimens and Occurrence Frequency Obtained from Inside and Outside the Reefs by Bottom Gill Net during the Second Survey off Petchaburi

Petchaburi 2nd Survey Bottom Gill Net	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Orectolobidae	191		88.0	1.00	6		42.8	1.00
Chiloscyllium punctatum		15	6.9	1.00		2	14.3	0.50
Chiloscyllium griseum		176	81.1	1.00		4	28.6	0.75
Dasyatidae	8		3.7	0.75	6		42.8	0.75
Taeniura lymma		8	3.7	0.75		-	-	-
Dasyatis imbricus		-				5	35.7	0.75
Dasyatis sp.		-				1	7.1	0.25
Myliobatidae	1		0.5	0.25	-		-	-
Aetobatus narinari		1	0.5	0.25		-	-	-
Lutjanidae	1		0.5	0.25	1		7.1	0.25
Lutjanus russelli		1	0.5	0.25		1	7.1	0.25
Leiognathidae	1		0.5	0.25	-		-	-
Leiognathus brevirostris		1	0.5	0.25		-	-	-
Pomadasyidae	3		1.4	0.75	-		-	-
Plectorhynchus pictus		3	1.4	0.75		-	-	-
Sciaenidae	1		0.5	0.25	-		-	-
Johnius carutta		1	0.5	0.25		-	-	-
Ephippidae	7		3.2	0.75	-		-	-
Drepane punctata		7	3.2	0.75		-	-	-
Siganidae	1		0.5	0.25	-		-	-
Siganus javus		1	0.5	0.25		-	-	-
Aluteridae	1		0.5	0.25	1		7.1	0.25
Monacanthus chinensis		1	0.5	0.25		1	7.1	0.25
Ostraciontidae	1		0.5	0.25	-		-	-
Ostracion tuberculatus		1	0.5	0.25		-	-	-
Diodontidae	1		0.5	0.25	-		-	-
Diodon liturosus		1	0.5	0.25		-	-	-
Total	217	217	100.0	4 hauls	14	14	100.0	4 hauls

Table 4.14 Number of Specimens and Occurrence Frequency Obtained from Both Inside and Outside the Reefs by Handline during the Second Survey off Petchaburi

Petchaburi 2nd Survey Handline	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Orectolobidae	7		16.7	0.20	-		-	-
Chiloscyllium griseum		7	16.7	0.20		-	-	-
Serranidae	9		21.4	0.40	2		40.0	1.00
Epinephelus bleekeri		2	4.8	0.20		2	40.0	1.00
Epinephelus tauvina		7	16.7	0.20				
Lutjanidae	25		59.5	0.80	3		60.0	1.00
Lutjanus russelli		11	26.2	0.80		2	40.0	1.00
Lutjanus vitta		9	21.4	0.20		1	20.0	1.00
Lutjanus lineolatus		2	4.8	0.20		-	-	-
Lutjanus johni		3	7.1	0.20		-	-	-
Scatophagidae	1		2.4	0.20	-		-	-
Scatophagus argus		1	2.4	0.20		-	-	-
Total	42	42	100.0	5 times	5	5	100.0	1 time

Table 4.15 Number of Specimens and Occurrence Frequency Obtained from Both Inside and Outside the Reefs by Trap during the Second Survey off Petchaburi

Petchaburi 2nd Survey Trap	Inside the Reefs				Outside the Reefs			
	no. of specimens		%	Occurrence frequency	no. of specimens		%	Occurrence frequency
	Family	Species			Family	Species		
Serranidae	2		18.2	0.33	1		25.0	0.33
Epinephelus tauvina		1	9.1	0.33		1	25.0	0.33
Cephalopholis pachycentron		1	9.1	0.33				
Lutjanidae	5		45.5	0.67	1		25.0	0.33
Lutjanus lineolatus		1	9.1	0.33		-	-	-
Lutjanus russelli		2	18.2	0.67		1	25.0	0.33
Lutjanus vitta		2	18.2	0.33		-	-	-
Sciaenidae	-		-	-	1		25.0	0.33
Johnius carutta		-	-	-		1	25.0	0.33
Aluteridae	2		18.2	0.33	1		25.0	0.33
Monacanthus chinensis		2	18.2	0.33		1	25.0	0.33
Ostraciontidae	2		18.2	0.33	-		-	-
Ostracion tuberculatus		2	18.2	0.33		-	-	-
Total	11	11	100.0	3 traps	4	4	100.0	3 traps

Table 4.16 Catch Quantity and Average Rate of Catch by Bottom Gill Net Inside the Reefs during the Three Surveys off Rayong

Inside the Reefs Bottom Gill Net	1st Survey			2nd Survey			3rd Survey		
	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)
Orectolobidae	4578	38.3	76.3	4530	57.6	125.8	-	-	-
Chiloscyllium punctatum	4578	38.3	76.3	4530	57.6	125.8	-	-	-
Dasyatidae	2684	22.4	44.7	1295	16.4	36.0	6552	70.5	109.2
Taeniura lymma	2684	22.4	44.7	1295	16.4	36.0	6552	70.5	109.2
Muraenidae	1659	13.9	27.7	-	-	-	-	-	-
Gymnothorax pictus	1659	13.9	27.7	-	-	-	-	-	-
Holocentridae	582	4.8	9.7	219	2.8	6.1	203	2.2	5.6
Myripristis hexagonus	582	4.8	9.7	-	-	-	-	-	-
Sargocentron rubrum	-	-	-	219	2.8	6.1	203	2.2	5.6
Serranidae	418	3.5	7.0	-	-	-	-	-	-
Cephalopholis boenack	418	3.5	7.0	-	-	-	-	-	-
Latidae	208	1.7	3.5	-	-	-	-	-	-
Psammoperca waigiensis	208	1.7	3.5	-	-	-	-	-	-
Carangidae	-	-	-	65	0.8	1.8	214	2.3	5.9
Selaroides leptolepis	-	-	-	65	0.8	1.8	-	-	-
Alepes macrurus	-	-	-	-	-	-	214	2.3	5.9
Lutjanidae	-	-	-	-	-	-	69	0.7	1.9
Lutjanus lineolatus	-	-	-	-	-	-	69	0.7	1.9
Nemipteridae	198	1.6	3.3	-	-	-	25	0.3	0.7
Scolopsis ciliatus	198	1.6	3.3	-	-	-	-	-	-
Scolopsis cancellatus	-	-	-	-	-	-	25	0.3	0.7
Leiognathidae	4	0.03	0.1	-	-	-	-	-	-
Secutor indicius	4	0.03	0.1	-	-	-	-	-	-
Pomadasyidae	-	-	-	439	5.6	12.2	1995	21.5	55.4
Plectorhynchus pictus	-	-	-	439	5.6	12.2	1995	21.5	55.4
Chaetodontidae	66	0.6	1.1	-	-	-	-	-	-
Chelmo rostratus	66	0.6	1.1	-	-	-	-	-	-
Labridae	728	6.1	12.1	-	-	-	-	-	-
Choerodon schoenleini	728	6.1	12.1	-	-	-	-	-	-

Table 4.16 (Continued)

Inside the Reefs Bottom Gill Net	1st Survey			2nd Survey			3rd Survey		
	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)
Siganidae	-	-	-	32	0.4	0.9	3	0.03	0.08
Siganus javus	-	-	-	32	0.4	0.9	-	-	-
Siganus oramin	-	-	-	-	-	-	3	0.03	0.08
Scorpaenidae	75	0.6	1.3	-	-	-	-	-	-
Scorpaenopsis cirrhosa	75	0.6	1.3	-	-	-	-	-	-
Bothidae	-	-	-	-	-	-	43	0.5	1.2
Pseudorhombus elevatus	-	-	-	-	-	-	43	0.5	1.2
Aluteridae	-	-	-	1290	16.4	35.8	-	-	-
Aluterus monoceros	-	-	-	1290	16.4	35.8	-	-	-
Ostraciontidae	764	6.4	12.7	-	-	-	191	2.1	5.3
Rhynchostracion nasus	764	6.4	12.7	-	-	-	191	2.1	5.3
Total	11964	100.0	199.4	7870	100.0	218.6	9295	100.0	258.2

Table 4.17 Catch Quantity and Average Rate of Catch by Bottom Gill Net Outside the Reefs during the Three Surveys off Rayong

Outside the Reefs Bottom Gill Net	2nd Survey			3rd Survey		
	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)
Dasyatidae	0	-	-	449	16.2	12.5
Dasyatis sp.	0	-	-	169	6.1	4.7
Dasyatis imbricatus	0	-	-	280	10.1	7.8
Carangidae	0	-	-	1613	58.2	44.8
Caranx macrurus	0	-	-	1613	58.2	44.8
Nemipteridae	0	-	-	71	2.6	2.0
Scolopsis cancellatus	0	-	-	71	2.6	2.0
Platycephalidae	0	-	-	637	23.0	17.7
Platycephalus indicus	0	-	-	637	23.0	17.7
Total	0	-	-	2770	100.0	76.9

Note: During the 1st Survey Bottom Gill Net was only employed inside the reefs.

Table 4.18 Catch Quantity and Average Rate of Catch by Handline Inside the Reefs during the Three Surveys off Rayong

Inside the Reefs Handline	1st Survey			2nd Survey			3rd Survey		
	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)
Muraenidae	418	7.4	59.7	-	-	-	-	-	-
Gymnothorax pictus	418	7.4	59.7	-	-	-	-	-	-
Holocentridae	-	-	-	-	-	-	77	0.8	8.6
Sargocentron rubrum	-	-	-	-	-	-	77	0.8	8.6
Serranidae	656	11.6	93.7	428	6.9	107.0	905	9.0	100.6
Epinephelus megachir	110	1.9	15.7	207	3.3	51.7	-	-	-
Epinephelus bleekeri	333	5.9	47.6	221	3.6	55.3	583	5.8	64.8
Cephalopholis pachycentron	21	0.4	3.0	-	-	-	-	-	-
Cephalopholis boenack	192	3.4	27.4	-	-	-	322	3.2	35.8
Lutjanidae	1361	24.1	194.4	3914	63.3	978.5	5650	56.3	627.8
Lutjanus vitta	1361	24.1	194.4	3914	63.3	978.5	4295	42.8	477.2
Lutjanus russelli	-	-	-	-	-	-	353	3.5	39.2
Lutjanus lineolatus	-	-	-	-	-	-	1002	10.0	111.3
Nemipteridae	1030	18.2	147.1	-	-	-	1220	12.1	135.6
Nemipterus tolu	45	0.8	6.4	-	-	-	-	-	-
Nemipterus hexodon	-	-	-	-	-	-	133	1.3	14.8
Scolopsis ciliatus	795	14.1	113.6	-	-	-	327	3.2	36.3
Scolopsis dubiosus	-	-	-	-	-	-	649	6.5	72.1
Scolopsis temporalis	-	-	-	-	-	-	111	1.1	12.3
Scolopsis vosmeri	190	3.4	27.1	-	-	-	-	-	-
Pentapodidae	-	-	-	-	-	-	81	0.8	9.0
Pentapodus setosus	-	-	-	-	-	-	81	0.8	9.0
Pomadasyidae	420	7.4	60.0	-	-	-	224	2.2	24.9
Plectorhynchus pictus	420	7.4	60.0	-	-	-	224	2.2	24.9
Lethrinidae	1727	30.6	246.7	1845	29.8	461.3	1886	18.8	209.6
Lethrinus lentjan	1727	30.6	246.7	1845	29.8	461.3	1886	18.8	209.6
Labridae	32	0.6	4.6	-	-	-	-	-	-
Halichoeres nigrescens	32	0.6	4.6	-	-	-	-	-	-
Total	5644	100.0	806.3	6187	100.0	1546.8	10043	100.0	1115.9

Table 4.19 Catch Quantity and Average Rate of Catch by Handline Outside the Reefs during the Three Surveys off Rayong

Outside the Reefs Handline	2nd Survey			3rd Survey		
	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)
Nemipteridae	422	72.9	422.0	232	15.5	116.0
Nemipterus hexodon	422	72.9	422.0	232	15.5	116.0
Pentapodidae	96	16.6	96.0	474	31.7	237.0
Pentapodus setosus	96	16.6	96.0	474	31.7	237.0
Theraponidae	61	10.5	61.0	788	52.7	394.0
Therapon jarbua	61	10.5	61.0	788	52.7	394.0
Total	579	100.0	579.0	1494	100.0	747.0

Note: During the 1st Survey Handlines were only employed inside the reefs.

Table 4.20 Catch Quantity and Average Rate of Catch by Trap Inside the Reefs during the Three Surveys off Rayong

Inside the Reefs Trap	1st Survey			2nd Survey			3rd Survey		
	Catch	%	Average rate (g/trap)	Catch	%	Average rate (g/trap)	Catch	%	Average rate (g/trap)
Dasyatidae	-	-	-	-	-	-	651	44.3	162.8
Taeniura lymma	-	-	-	-	-	-	651	44.3	162.8
Muraenidae	801	22.6	100.1	1829	25.4	457.3	454	30.9	113.5
Gymnothorax pictus	801	22.6	100.1	1829	25.4	457.3	454	30.9	113.5
Holocentridae	666	18.8	83.2	45	0.6	11.3	121	8.2	30.3
Myripristis hexagonus	666	18.8	83.2	-	-	-	-	-	-
Sargocentron rubrum	-	-	-	45	0.6	11.3	121	8.2	30.3
Latidae	462	13.0	57.8	-	-	-	-	-	-
Psammoperca waigiensis	462	13.0	57.8	-	-	-	-	-	-
Apogonidae	8	0.2	1.0	-	-	-	-	-	-
Archamia lineolata	8	0.2	1.0	-	-	-	-	-	-
Lutjanidae	273	7.7	34.1	4310	59.9	1077.5	65	4.4	16.3
Lutjanus vitta	273	7.7	34.1	-	-	-	25	1.7	6.3
Lutjanus lineolatus	-	-	-	4310	59.9	1077.5	40	2.7	10.0
Nemipteridae	103	2.9	12.9	-	-	-	-	-	-
Scolopsis vosmeri	103	2.9	12.9	-	-	-	-	-	-
Mullidae	416	11.7	52.0	-	-	-	-	-	-
Upeneus tragula	416	11.7	52.0	-	-	-	-	-	-
Chaetodontidae	582	16.4	72.8	-	-	-	-	-	-
Chelmo rostratus	582	16.4	72.8	-	-	-	-	-	-
Siganidae	191	5.4	23.9	1012	14.1	253.0	-	-	-
Siganus oramin	191	5.4	23.9	-	-	-	-	-	-
Siganus javus	-	-	-	1012	14.1	253.0	-	-	-
Ostraciontidae	44	1.2	5.5	-	-	-	180	12.2	45.0
Ostracion tuberculatus	44	1.2	5.5	-	-	-	180	12.2	45.0
Total	3546	100.0	443.3	7196	100.0	1799.0	1471	100.0	367.8

Table 4.21 Catch Quantity and Average Rate of Catch by Trap Outside the Reefs during the Three Surveys off Rayong

Outside the Reefs Trap	2nd Survey			3rd Survey		
	Catch	%	Average rate (g/trap)	Catch	%	Average rate (g/trap)
Muraenidae	1672	51.8	418.0	1912	49.0	478.0
Gymnothorax pictus	1672	51.8	418.0	1912	49.0	478.0
Serranidae	232	7.2	58.0	-	-	-
Epinephelus bleekeri	232	7.2	58.0	-	-	-
Apogonidae	-	-	-	770	19.7	192.5
Archamia lineolata	-	-	-	770	19.7	192.5
Lutjanidae	132	4.1	33.0	-	-	-
Lutjanus vitta	132	4.1	33.0	-	-	-
Nemipteridae	579	17.9	144.8	967	24.8	241.8
Scolopsis temporalis	579	17.9	144.8	138	3.5	34.5
Scolopsis cancellatus	-	-	-	829	21.3	207.3
Pentapodidae	520	16.1	130.0	-	-	-
Pentapodus setosus	520	16.1	130.0	-	-	-
Pomadasyidae	51	1.6	12.8	-	-	-
Plectorhynchus pictus	51	1.6	12.8	-	-	-
Mullidae	-	-	-	55	1.4	13.8
Upeneus tragula	-	-	-	55	1.4	13.8
Siganidae	-	-	-	13	0.3	3.3
Siganus oramin	-	-	-	13	0.3	3.3
Aluteridae	43	1.3	10.8	182	4.7	45.5
Cantherines macrurus	35	1.1	8.8	-	-	-
Monacanthus chinensis	8	0.2	2.0	182	4.7	45.5
Total	3229	100.0	807.3	3899	100.0	974.8

Note: During the 1st Survey Traps were only employed inside the reefs.

Table 4.22 Catch Quantity and Average Rate of Catch by Bottom Gill Net Inside the Reefs during the the Two Surveys off Petchaburi

Inside the Reefs Bottom Gill Net	1st Survey			2nd Survey		
	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)
Orectolobidae	110596	90.9	4173.4	173510	94.2	3098.4
Chiloscyllium punctatum	28002	23.0	1056.7	27693	15.0	494.5
Chiloscyllium griseum	82594	67.9	3116.8	145817	79.2	2603.9
Dasyatidae	6000	4.9	226.4	5774	3.1	103.1
Taeniura lymma	6000	4.9	226.4	5774	3.1	103.1
Myliobatidae	-	-	-	1408	0.8	25.1
Aetobatus narinari	-	-	-	1408	0.8	25.1
Serranidae	1557	1.3	58.8	-	-	-
Epinephelus tauvina	1557	1.3	58.8	-	-	-
Carangidae	41	0.03	1.5	-	-	-
Atule djeddaba	41	0.03	1.5	-	-	-
Lutjanidae	607	0.5	22.9	228	0.1	4.1
Lutjanus russelli	607	0.5	22.9	-	-	-
Lutjanus johni	-	-	-	228	0.1	4.1
Nemipteridae	141	0.1	5.3	-	-	-
Scolopsis ciliatus	141	0.1	5.3	-	-	-
Leiognathidae	-	-	-	21	0.01	0.4
Leiognathus brevirostris	-	-	-	21	0.01	0.4
Pomadasyidae	2596	2.1	98.0	832	0.5	14.9
Plectorhynchus pictus	2596	2.1	98.0	832	0.5	14.9
Sciaenidae	153	0.1	5.8	74	0.04	1.3
Johnius belengerii	153	0.1	5.8	-	-	-
Johnius carutta	-	-	-	74	0.04	1.3
Ephippidae	-	-	-	532	0.3	9.5
Drepane punctata	-	-	-	532	0.3	9.5
Siganidae	-	-	-	154	0.08	2.8
Siganus javus	-	-	-	154	0.08	2.8
Aluteridae	-	-	-	98	0.05	1.8
Monacanthus chinensis	-	-	-	98	0.05	1.8
Ostraciontidae	-	-	-	104	0.06	1.9
Ostracion tuberculatus	-	-	-	104	0.06	1.9
Diodontidae	-	-	-	1410	0.8	25.2
Diodon liturosus	-	-	-	1410	0.8	25.2
Total	121691	100.0	4592.1	184145	100.0	3288.3

Table 4.23 Catch Quantity and Average Rate of Catch by Bottom Gill Net Outside the Reefs during the Two Surveys off Petchaburi

Outside the Reefs Bottom Gill Net	2nd Survey		
	Catch	%	Average rate (g/hr)
Orectolobidae	6398	40.3	114.2
Chiloscyllium punctatum	3102	19.6	55.4
Chiloscyllium griseum	3296	20.8	58.9
Dasyatidae	8898	56.1	158.9
Dasyatis sp.	7500	47.3	133.9
Dasyatis imbricus	1398	8.8	25.0
Lutjanidae	468	3.0	8.4
Lutjanus russelli	468	3.0	8.4
Aluteridae	98	0.6	1.8
Monacanthus chinensis	98	0.6	1.8
Total	15862	100.0	283.3

Note: During the 1st Survey Bottom gill net was only employed inside the reefs.

Table 4.24 Catch Quantity and Average Rate of Catch by Handline Inside the Reefs during the Two Surveys off Petchaburi

Inside the Reefs Handline	1st Survey			2nd Survey		
	Catch	%	Average rate (g/hr)	Catch	%	Average rate (g/hr)
Orectolobidae	-	-	-	4796	47.1	479.6
Chiloscyllium griseum	-	-	-	4796	47.1	479.6
Serranidae	-	-	-	3166	31.1	316.6
Epinephelus bleekeri	-	-	-	215	2.1	21.5
Epinephelus tauvina	-	-	-	2951	28.9	295.1
Sillaginidae	345	26.2	115.0	-	-	-
Sillago maculata	42	3.2	14.0	-	-	-
Sillago sihama	303	23.0	101.0	-	-	-
Carangidae	55	4.2	18.3	-	-	-
Atule mate	55	4.2	18.3	-	-	-
Lutjanidae	514	39.0	171.3	2043	20.1	204.3
Lutjanus russelli	421	32.0	140.3	908	8.9	90.8
Lutjanus vitta	93	7.1	31.0	316	3.1	31.6
Lutjanus johni	-	-	-	760	7.5	76.0
Lutjanus lineolatus	-	-	-	59	0.6	5.9
Nemipteridae	232	17.6	77.3	-	-	-
Scolopsis ciliatus	232	17.6	77.3	-	-	-
Scatophagidae	170	12.9	56.7	179	1.7	17.9
Scatophagus argus	170	12.9	56.7	179	1.7	17.9
Total	1316	100.0	438.7	10184	100.0	1018.4

Table 4.25 Catch Quantity and Average Rate of Catch by Handline Outside the Reefs during the Two Surveys off Petchaburi

Outside the Reefs Handline	2nd Survey		
	Catch	%	Average rate (g/hr)
Serranidae	182	45.7	182.0
Epinephelus bleekeri	182	45.7	182.0
Lutjanidae	216	54.3	216.0
Lutjanus russelli	183	46.0	183.0
Lutjanus vitta	33	8.3	33.0
Total	398	100.0	398.0

Note: During the 1st Survey Hardlines were only employed inside the reefs.

Table 4.26 Catch Quantity and Average Rate of Catch by Trap Inside the Reefs during the Two Surveys off Petchaburi

Inside the Reefs Trap	1st Survey			2nd Survey		
	Catch	%	Average rate (g/trap)	Catch	%	Average rate (g/trap)
Orectolobidae	716	24.7	119.3	-	-	-
Chiloscyllium griseum	716	24.7	119.3	-	-	-
Plotosidae	149	5.1	24.8	-	-	-
Plotosus canius	149	5.1	24.8	-	-	-
Serranidae	-	-	-	623	45.3	207.7
Epinephelus tauvina	-	-	-	528	38.4	176.0
Cephalopholis pachycentron	-	-	-	95	6.9	31.7
Lutjanidae	1018	35.1	169.7	277	20.1	92.3
Lutjanus russelli	1018	35.1	169.7	184	13.4	61.3
Lutjanus vitta	-	-	-	69	5.0	23.0
Lutjanus lineolatus	-	-	-	24	1.7	8.0
Sciaenidae	580	20.0	96.7	-	-	-
Johnius belengerii	580	20.0	96.7	-	-	-
Aluteridae	335	11.6	55.8	334	24.3	111.3
Monacanthus chinensis	335	11.6	55.8	334	24.3	111.3
Ostraciontidae	-	-	-	142	10.3	47.3
Ostracion tuberculatus	-	-	-	142	10.3	47.3
Batrachoididae	101	3.5	16.8	-	-	-
Halophryne trispinosus	101	3.5	16.8	-	-	-
Total	2899	100.0	483.2	1376	100.0	458.7

Table 4.27 Catch Quantity and Average Rate of Catch by Trap Outside the Reefs during the Two Surveys off Petchaburi

Outside the Reefs Trap	2nd Survey		
	Catch	%	Average rate (g/trap)
Serranidae	28	11.4	9.3
Epinephelus tauvina	28	11.4	9.3
Lutjanidae	73	29.8	24.3
Lutjanus russelli	73	29.8	24.3
Sciaenidae	68	27.8	22.7
Johnius carutta	68	27.8	22.7
Aluteridae	76	31.0	25.3
Monacanthus chinensis	76	31.0	25.3
Total	245	100.0	81.7

Note: During the 1st Survey Traps were only employed inside the reefs.