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OCEANOGRAPHIC CONDITIONS IN THE COASTAL WATERS OFF RAYONG PROVINCE, THAILAND

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INTRODUCTION

This paper deals, in a comprehensive way, with the fisheries oceanographic conditions of the coastal waters off Rayong Province, Thailand. The paper is based mainly on the records collected during the survey conducted from 15 to 21 October 1984.

The locations of the oceanographic survey stations are shown in Fig. 1.

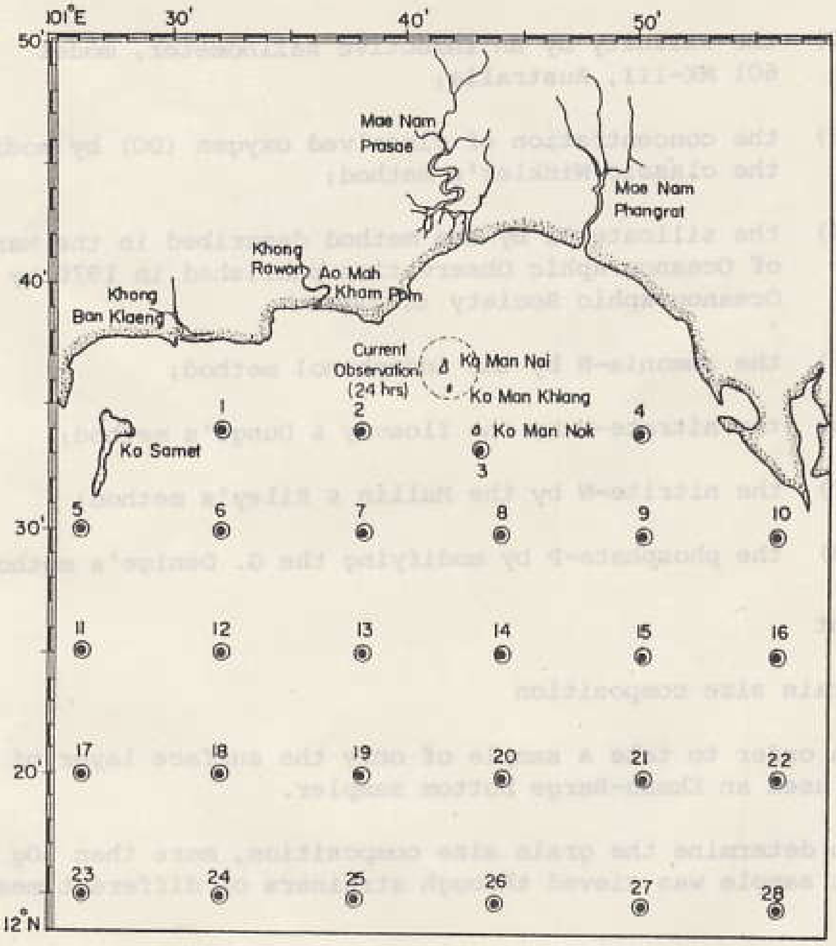

Fig. 1. Location chart of oceanographic survey stations (October 1984)

MATERIALS AND METHODS

1. Sea water

Sea water samples were collected by means of a Nansen reversing water bottle and a Van Dorn water sampler. For the chemical analysis, the water samples were filtered through a Whatman Glass microfiber filter (GF/A). Chemical and physical analyses were carried out on the following:

(1) the temperature by a reversing thermometer and a bathythermograph (BT);

(2) the salinity by an inductive salinometer, model 601 MK-III, Australia;

(3) the concentration of dissolved oxygen (DO) by modifying the classic Winkler's method;

(4) the silicate-Si by the method described in the Manual of Oceanographic Observation published in 1970 by the Oceanographic Society of Japan;

(5) the ammonia-N by the indophenol method;

(6) the nitrate-N by the Ilosvay & Dunge's method;

(7) the nitrite-N by the Mullin & Riley's method;

(8) the phosphate-P by modifying the G. Denige's mothod.

2. Sediment

(i) Grain size composition

In order to take a sample of only the surface layer of the bottom, we used an Ekman-Berge bottom sampler.

To determine the grain size composition, more than 50g (dry weight) of sediment sample was sieved through strainers of different mesh size.

(ii) Organic matter

The organic matter in the sediments was determined by the ignition loss method.

(iii) Calcium carbonate content

The calcium carbonate ($CaCO_3$) content in the sediments was determined by conversion from the ignited loss of carbondioxide (CO_2) evolved at 950°C according to DEAN (1974)[1].

(iv) COD and total sulphides

The chemical oxygen demand (COD) was determined by the reduction of permanganate when the organic matter had been completely oxidized. The total sulphides were measured by using the Gastic Hydrotec S Detector Kit.

3. Chlorophyll-a

The chlorophyll-a analysis was carried out or 5-litre water samples collected from the surface layer. The absorbencies at 664, 647 and 630 nm were determined.

4. Current

The current observation at 2 m depth was carried out for 24 hours by a T.S. self-recording current meter (DPCM-4).

RESULTS AND DISCUSSION

1. Topography

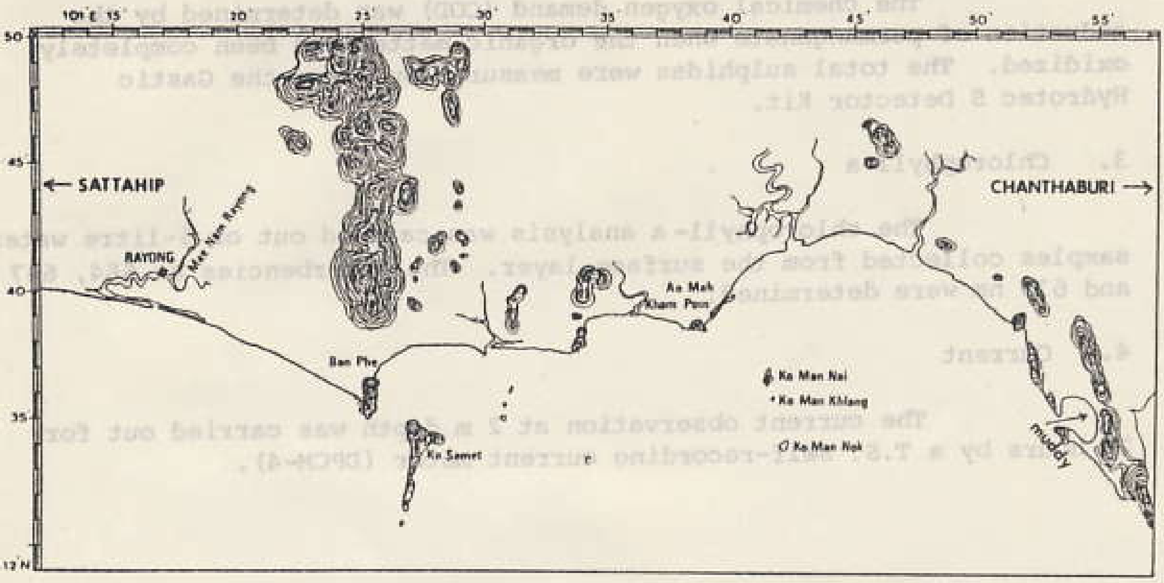

Fig. 2. Index map of coast line of Rayong Province, Thailand

In Rayong Province, the sandy beach along the coast of the Gulf extends for about one hundred kilometres between Sattahip and Chanthaburi, except where interrupted by a few headlands. Beaches with muddy sediments are rarely seen along the coast, however they are often found near the shoreline inside lagoons in the eastern parts.

The hill in Rayong Province as shown in Fig. 2 extends to the Gulf at Ban Phe. Samet Island is thought to be the southern extension of the hill group. Bleached quartz sands or white sands are widespread in Samet Island.

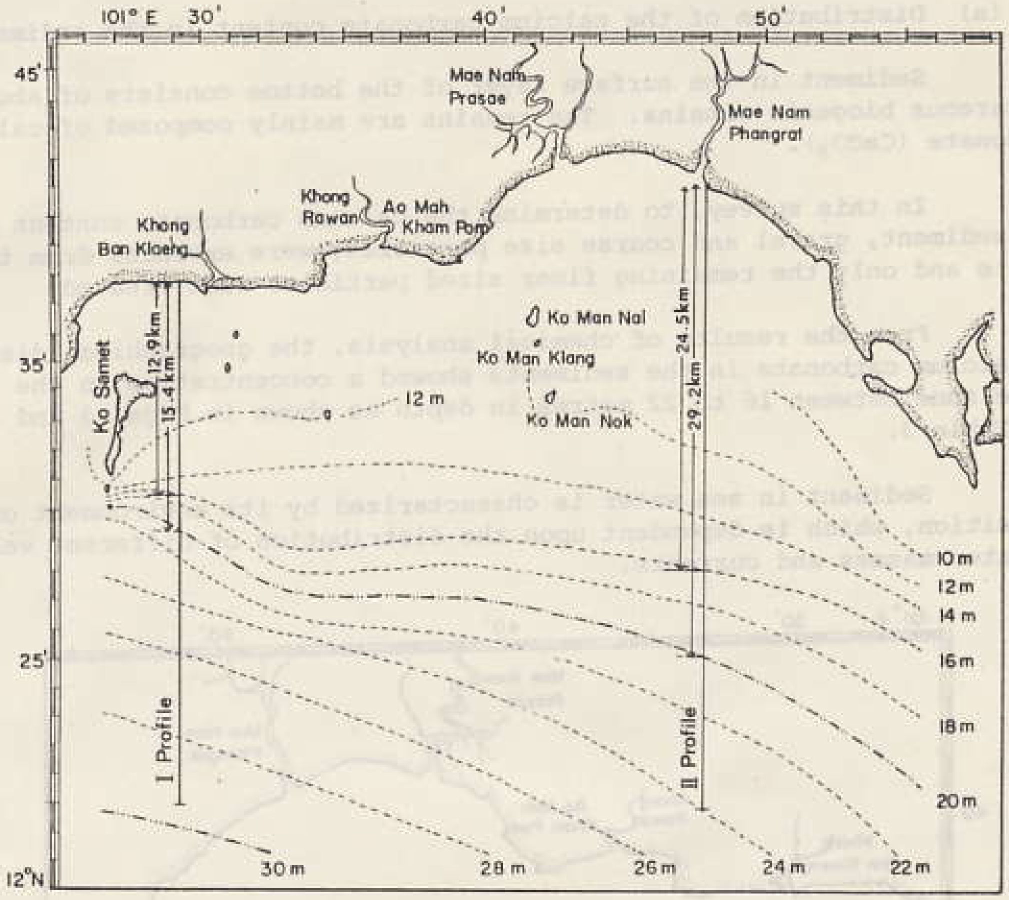

Fig. 3. The slope gradiant in waters off Rayong Province, Thailand
------ Depth contour marks.

The submarine topography of the surveyed area is shown in Fig. 3. Down to a depth of 14 metres, the contour lines are almost parallel to the shore and open towards the Gulf in the south.

The depth increases gradually to about 16 metres before until it reaches the ridge of the central depression of the Gulf, where the bottom can be clearly separated from the coastal waters because of a steeper slope.

In the western section (I profile in Fig. 3) the boundary of the bottom is situated in front of Samet Island at a distance of about 13 kilometres from the coast. Going eastwards (II profile in Fig. 3), the coastal slope becomes gentler and widens, and the ridge of the deperssion is located at about 30 kilometres from the coast.

2. Bottom sediment

(a) Distribution of the calcium carbonate content in the sediment

Sediment in the surface layer of the bottom consists of abundant calcareous biogenic remains. The remains are mainly composed of calcium carbonate ($CaCO_3$).

In this survey, to determine the calcium carbonate content in the sediment, gravel and coarse size particles, were excluded from the sample and only the remaining finer sized particles were treated.

From the results of chemical analysis, the geographical distribution of calcium carbonate in the sediments showed a concentration in the steeper slope zone between 16 to 22 metres in depth as shown in Figs. 3 and 4, and Table 3.

Sediment in sea water is characterized by its environment of deposition, which is dependent upon the distribution of different velocity of water masses and currents.

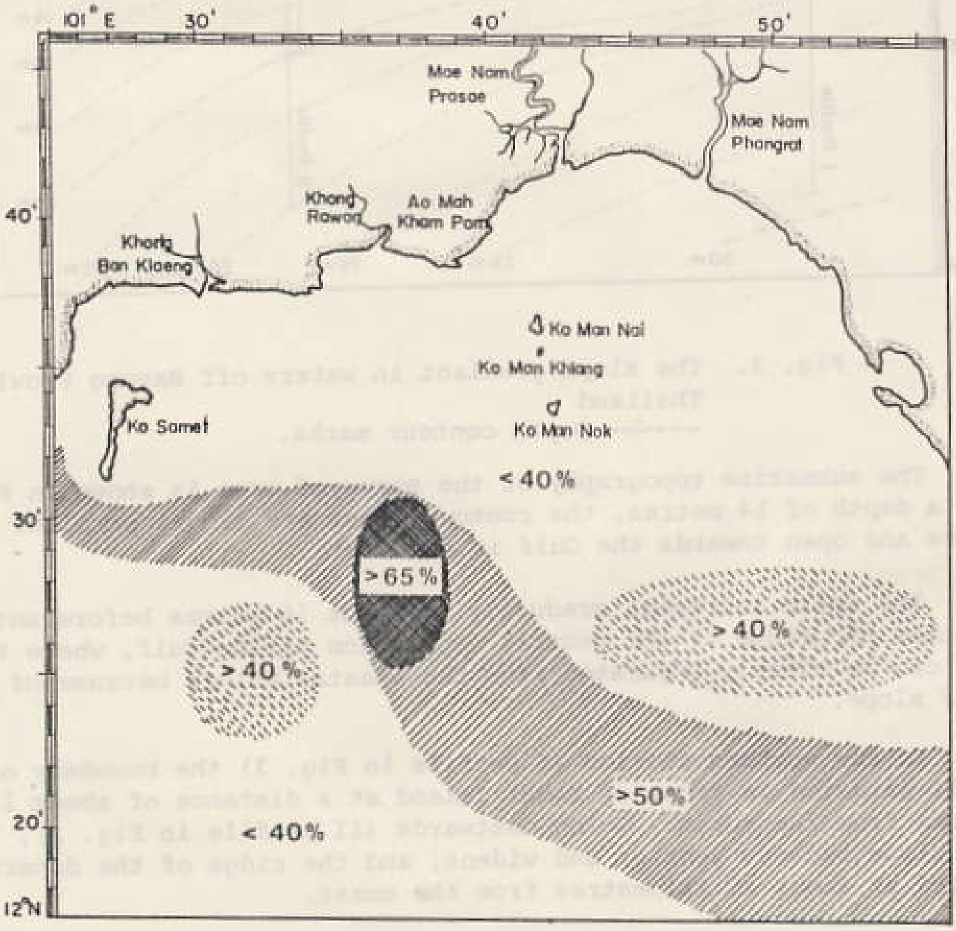

Fig. 4. Geographical distribution of calcium carbonate in the sediments in the waters off Rayong Province, Thailand.

(b) Grain size distribution

In general, the size classification of sediments is an adaptation of the systems proposed by WENTWORTH (1922) and KRUMBEIN (1934)[2], based on the following concept:

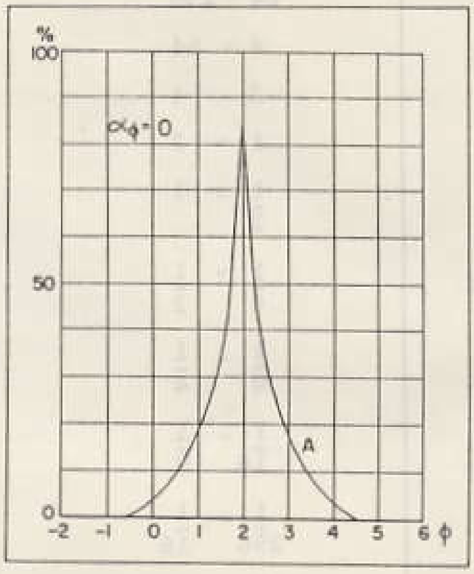

Fig. 5. Normal frequency distribution curve

$\alpha\phi$: Sorting

The curve showing the weight distribution as a function of the logarithm of particle size for sediments from a certain locality is usually similar to mormal distribution, when a sufficient amount of sediment is analysed. The word "sufficient", as used here, means that this amount will fulfill the basic statistical condition.

For convenience, the diameter of a particle "d", in millimetres, is replaced here by ϕ as expressed in the following equation:

$$d = \frac{1}{2^{\phi}} = 2^{-\phi} \quad \text{or} \quad \log_{10} d = -\phi \log_{10} 2$$

The logarithmic scale of d corresponds to the linear scale of ϕ.

The classification is as follows:

Terminology	Class range in mm	Class range in phi units
Boulders	> 256	-8 ø
Cobbles	64 ~ 256	-6 ~ -8 ø
Pebbles	4 ~ 64	-2 ~ -6 ø
Granules	2 ~ 4	-1 ~ 0 ø
Very coarse sand	1 ~ 2	0 ~ -1 ø
Coarse sand	$\frac{1}{2}$ ~ 1	1 ~ 0 ø
Medium sand	$\frac{1}{4}$ ~ $\frac{1}{2}$	2 ~ 1 ø
Fine sand	$\frac{1}{8}$ ~ $\frac{1}{4}$	3 ~ 2 ø
Very fine sand	$\frac{1}{16}$ ~ $\frac{1}{8}$	4 ~ 3 ø
Silt	$\frac{1}{256}$ ~ $\frac{1}{16}$	8 ~ 4 ø
Clay	< $\frac{1}{256}$	8 ø

However, sediments in the Gulf consist of abundant calcareous biogenic remains as mentioned above. Their shapes are varied: rod-like, plate-like, or of some other non-spherial forms reflecting their original morphology. Gravel and the coarse particles of the sediment samples mainly consisted of such calcareous biogenic remains and the specific gravity of the remains differed from that of sand. The sediment samples were inadequate for granulometric analysis to estimate the hydraulic condition according to the classification proposed by WENTWORTH and KRUMBEIN.

Therefore, we excluded gravel and coarse particles and treated only the sandy and muddy portion in this survey.

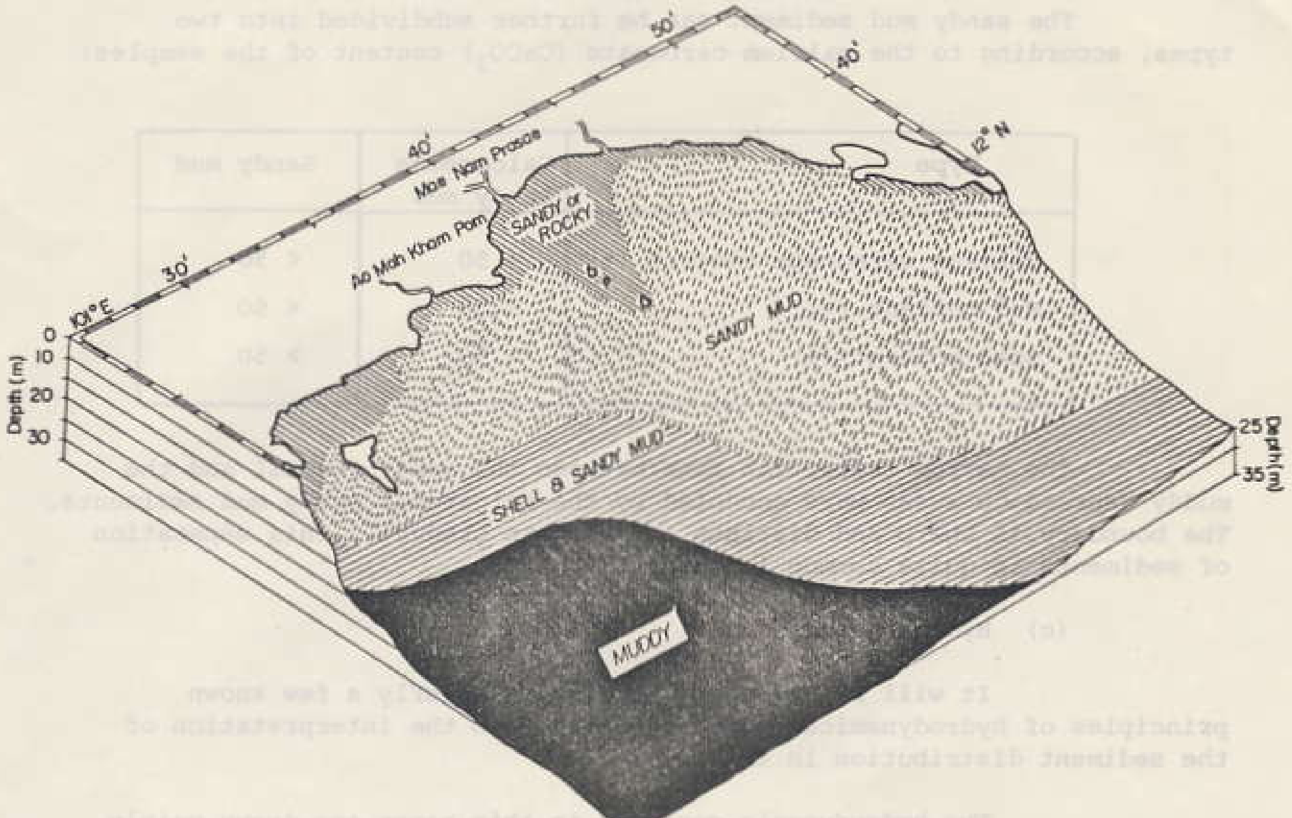

Fig. 6. Grain size distribution of sediments in the waters off Rayong Province, Thailand.

Based on the results obtained from the surveys conducted from July 1982 to June 1983 and from 15 to 21 October 1984, as shown in Fig. 6 and Table 4, the grain size distribution of sediments in the waters off Rayong Province falls roughly into two groups separated at about the 22 metres depth contour.

One is the sandy mud area, with a mud content of less than 50 per cent, extending shoreward of this contour. The configuration of this area is irregular due to the numerous small Islands and headlands along the coast where rocky Sediments have formed. The other is the muddy sand area in the depression deeper than twenty-two metres in depth, where the mud content is more than 50 per cent and the configuration is flat.

The sandy mud sediment can be further subdivided into two types, according to the calcium carbonate ($CaCO_3$) content of the samples:

Type	Calcareous sandy mud	Sandy mud
Calcium carbonate content (%)	> 50	< 50
Mud content (%)	< 50	< 50
Sand content (%)	> 50	> 50

The narrow transition zone between the sandy coastal and the muddy depression areas were occupied by the calcareous sandy mud sediments. The boundary is sharp and distinct rather than gradual. This separation of sediments is quite common in nature.

(c) Hydrodynamics

It will be necessary to discuss briefly a few known principles of hydrodynamics before entering into the interpretation of the sediment distribution in this area.

The hydrodynamic concepts in this paper are drawn mainly from the report written by N. NASU (1956)[3].

Since the size, shape, and the specific gravity of sediment components are directly related to the mechanics of transportation, this section is concerned primarily with the results of the particle size distribution of the mineral sediments.

(i) Settling velocity of particles

The settling velocity of sands corresponds to the transition range of the Stokes law to the Impact law and the mud corresponds to the Stokes law as shown in Fig. 7.

The sand rapidly settles to the bottom when the water loses its transporting power, while the mud particles are held in suspension for a longer period of time and are transported for a longer distance by advection as well as by the horizontal turbulence in the water because of their slow rate of settling.

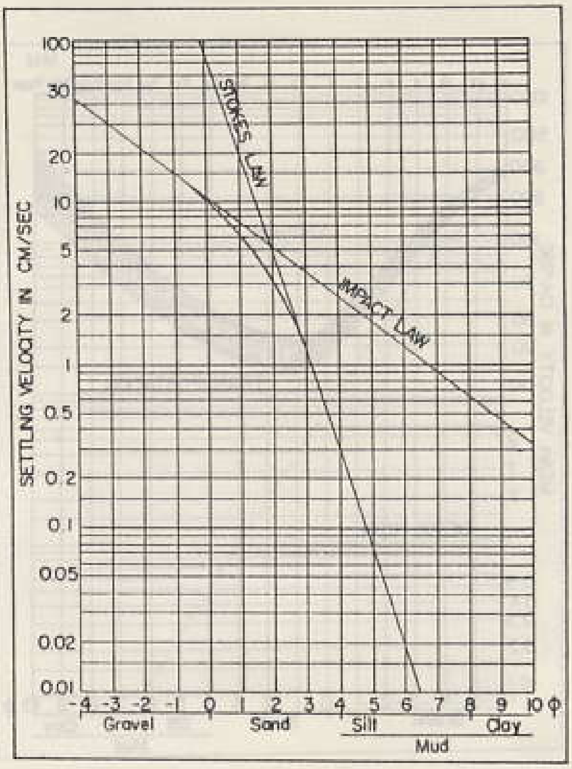

Fig. 7. Settling velocity of quartz spheres in 20°C sea water of salinity 35‰ in terms of their diameter (N. NASU, 1956)[3]

On the other hand, the current velocities caused by waves along the bottom are sometimes strong enough to churn up the sediments around the surf zone. Therefore, mud fractions on the bottom are put into suspension and scattered offshore by the horizontal water exchanges, and are not able to remain close to the shore. Only the sand sediments are able to stay along the shore.

(ii) Threshold velocity of bottom sediment

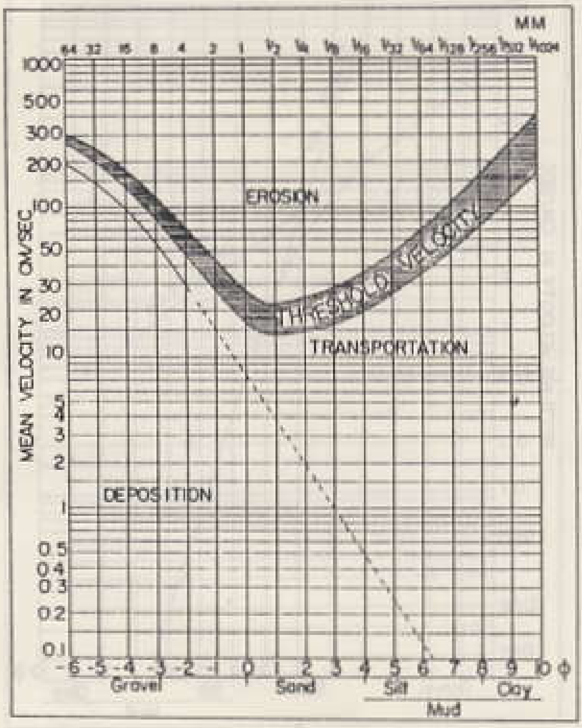

Fig. 8. Threshold mean flow velocity of particles in water (N. NASU, 1956)[3]

The critical value of the friction velocity which causes a certain size sediment to begin motion is called "Threshold velocity"

The threshold velocity for the transportation of sediment is minimal for fine sand size as shown in Fig. 8.

The settled mud does not start to move at the velocity at which fine sand initiates its motion. One possible cause may be the existence of the bottom laminar boundary layer when the bottom surface consisting of mud is smooth, but the cause is doubtful when the bottom is rough. That is, although sand shift easily, the settling velocity is so fast that they settle back to the bottom quickly.

Applying the hydrodynamical factors mentioned above to the fragment of calcareous biogenic remains, the velocities can be shown as follows:

(1) the settling velocity is very slow since it has a smaller value of specific gravity than that of sands, and

(2) the threshold velocity is smaller than that for mud, because the bottom surface containing calcareous biogenic remains is not smooth.

Consequently, as shown in Figs. 4 and 6, it has been observed in the waters off Rayong Province that there is a sharp boundary between sandy and muddy areas which are occupied clearly by calcareous sandy mud sediments. It can be understood that the distribution of can be attributed to sediments is due to hydrodynamical factors.

(d) Limited depth of wave disturbances on the bottom

When the waves approach diagonally towards the shore, the sands are shifted gradually parallel to the shore along the surf zone in the direction of the longshore current, the migrate easily along the shore from their supply sources.

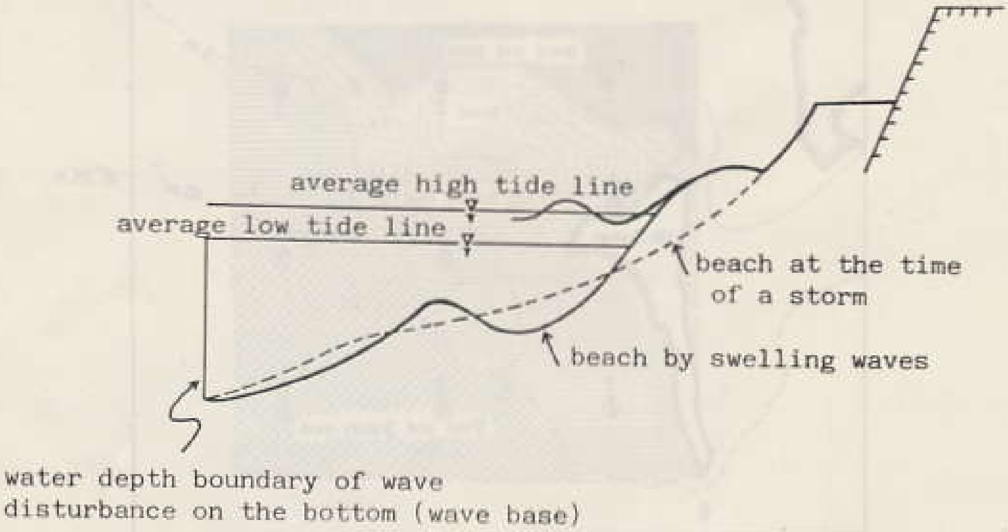

Fig. 9. Typical cross-section of a beach

The movement of drifting sand on the shore side of sandy coastal areas is extensive, and a seasonal movement of more than 5 metres owing to sediment and erosion is not rare in Japan[4].

For this reason artificial reefs can not escape caving in when they are placed on the movement zone of drifting sand.

The data on the distribution of grain size of sediments in the waters off Ban Phe, Rayong Province, obtained from the survey[5] conducted from July 1982 to June 1983, are shown in Table 1 and graphically in Fig. 10.

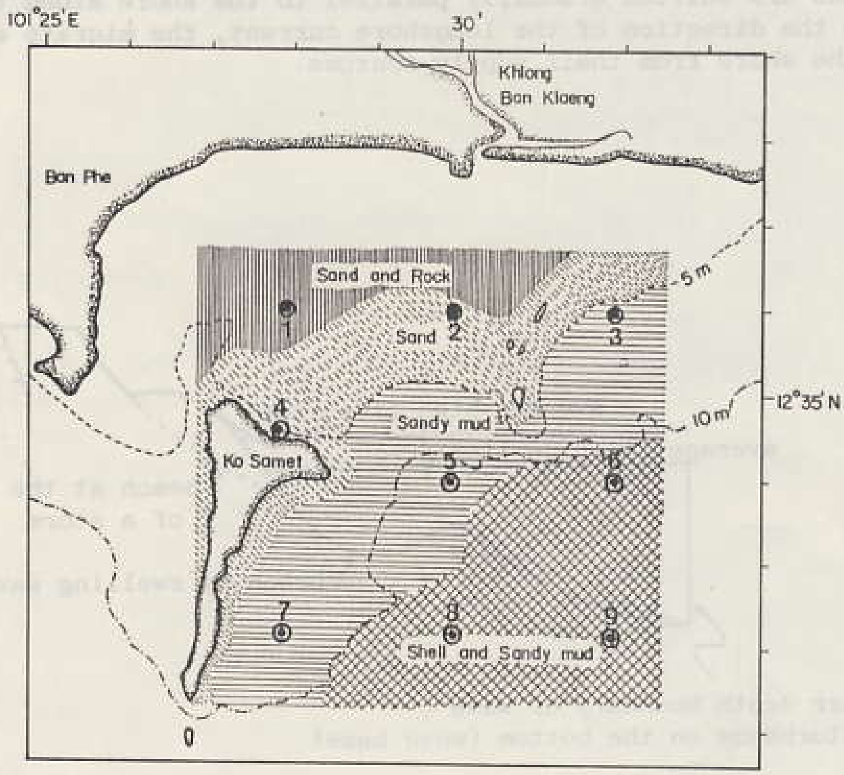

Fig. 10. Distribution of bottom sediments in the survey area (July 1982 to June 1983)

Table 1. The proportion (%) of sand, mud and shell in sediments of the survey area off Ban Phe, Rayong Province, Thailand, 1982-1983

Size (mm) / St.No.	Mud < 0.05	Fine sand 0.05-0.50	Coarse sand 0.50-3.0	Shell > 3.0
1	4.18	86.57	9.25	
2	4.00	89.20	5.80	1.00
3	13.70	85.60	0.40	0.30
4	6.99	85.63	6.88	0.50
5	22.60	76.70	0.66	0.04
6	16.50	60.00	※ 19.10	4.40
7	16.00	80.70	3.10	0.20
8	12.50	57.10	※ 20.90	9.50
9	6.20	47.00	※ 31.50	15.30

※ : Mixed shell fragments and sand

It can be seen from the figure and table that there is a sharp boundary between sand and sandy mud areas at an approximate depth of 5 metres. Well sorted sand occupied the area shallower than this depth and the mud content in the bottom sediment suddenly started to increase beyond this depth of water.

It seems that the five metres depth in the area off Ban Phe represents the depth limit of wave disturbance on the bottom from the point of new of hydrodynamics.

KING, C.A.M. (1951)[6] has mentioned that the depth of disturbance in the sand along the bottom corresponds to the wave height.

3. Current

A twenty-four hour anchor station was set up on 16-17 October 1984 off Man Nai Island. Observations of the current movement were made at a depth of 2.0 metres below the surface. The direction histogram was obtained by constructing the direction frequency of the current observed at hourly intervals. In Fig. 11 the current data are summarized in direction histograms on a map to indicate the geographical location.

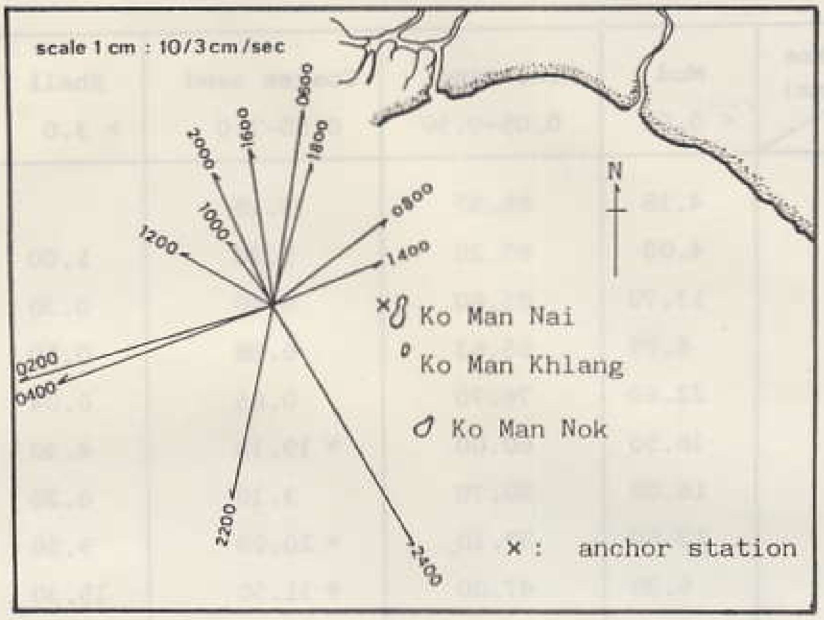

Fig. 11. Histograms of the current direction in the 2-metre layer nearest the surface off Man Nai Island (October 1984)

The direction of the current changed frequently and no dominant direction could be found. This indicates that the observation area was in waters with eddies, which are known to be caused by topographical features such as islands, shoals, etc. A considerably high current velocity occurred during the period of the low tide as shown in Table 2 and Fig. 11. The maximum was 0.4 knots (21 cm/sec).

4. Flow pattern of water

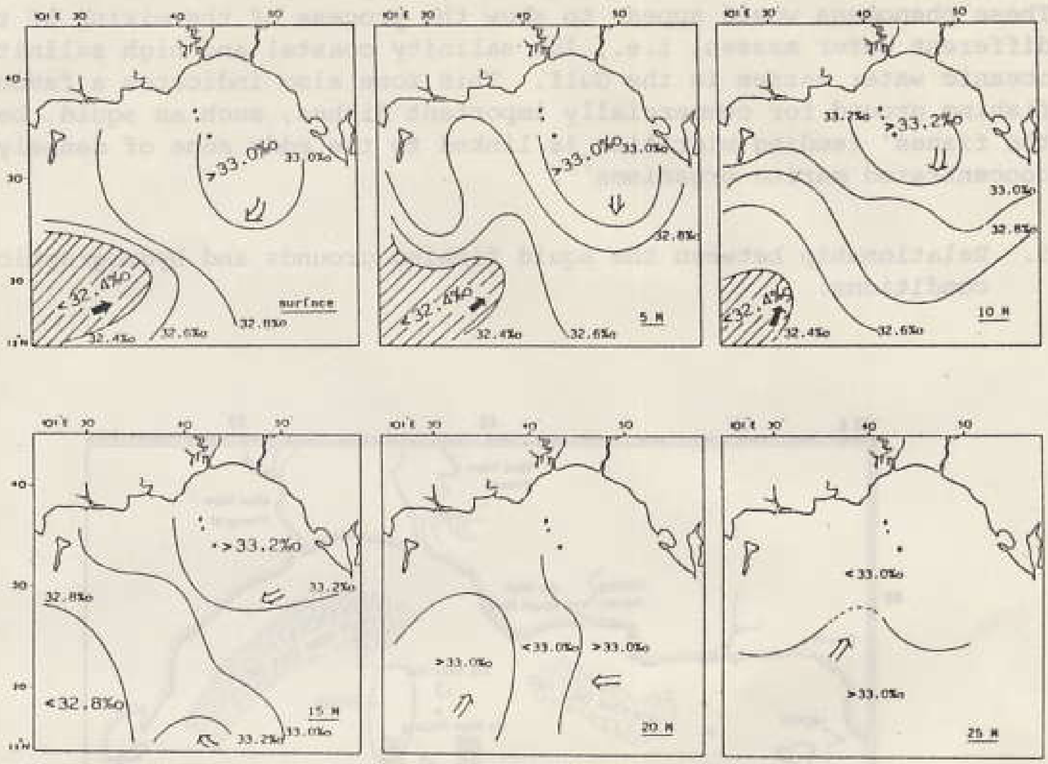

Fig. 12. Horizontal distribution of water salinity at 0, 5, 10, 15, 20 and 25 metres in depth in the survey area at high tide (October 1984)

⇐ : High salinity water mass

⬅ : Low salinity water mass

The water in a shallow sea shows considerable variations in the hydrographic conditions owing to meteorological causes and tidal flows. Temperature and salinity observations were carried out during high tide on one day in the survey period. (see Table 5).

As shown in Fig. 12 and Table 6, we observed, in waters shallower than 15 metres in depth a certain phase of the collision of water masses of two different salinities i.e. one more than 33 and the other less than 32.4 per mill of salinity.

This collision of two different water masses represents a front, which shifts to and fro, according to the prevalence of the masses on each side, resulting in the formation of dynamic eddies in this zone. These phenomena would appear to show the process of the mixing of two different water masses, i.e., low salinity coastal and high salinity oceanic water masses in the Gulf. This zone also indicates a favourable fishing ground for commercially important fishes, such as squid, because the fishes' feeding migration is linked to the eddy zone of densely concentrated marine organisms[7].

5. Relationship between the squid fishing grounds and hydrographic conditions.

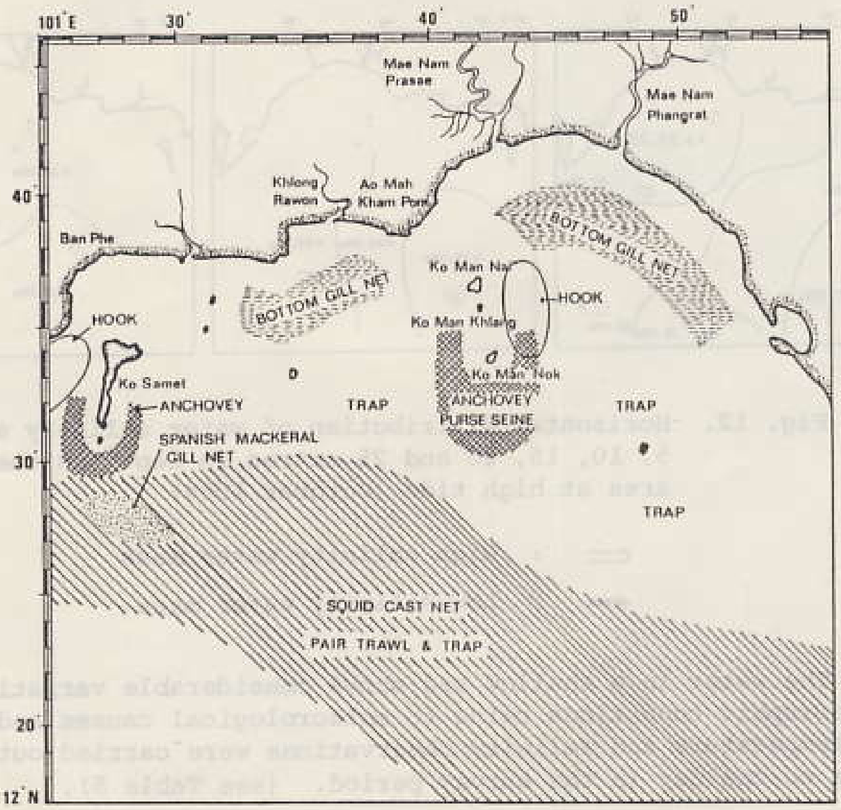

Fig. 13. Areas of major fishing operation off Rayong Province, Thailand (1984)

Squid and cuttlefish (from now on, squid and cuttlefish will be refered to as squid) production in value constituted as much as 20 per cent of the total marine fish production from the Gulf in 1983[8]. Squid fishery is one of the most important fisheries in Thailand.

Ban Phe fishing port is the main base for squid fishing operations in the Gulf and the richest of the fishing grounds is found in the waters deeper than 16 metres off Rayong Province as shown in Fig. 13.

According to the Fishery Statistical Bulletin for the South China Sea Area (1983)[8], the squid catch in the Gulf was mainly taken by squid cast net fishing boats and trawlers.

Therefore, from the results mentioned above, we can determine from the following features the squid fishing grounds in these waters:

(1) Depth	:	The most catchable depth in the Gulf is 15 to 30 metres for squid.
(2) Bottom Topography	:	The fishing operation areas are concentrated in the steeper slope zone along the coast.
(3) Bottom sediment	:	The bottom sediments of the grounds consist of abundant fine calcareous biogenic remains.
(4) Flow pattern of water	:	Squid is attracted to areas of stagnant waters or eddies, and not to places where strong currents prevail.

These hydrographic features of the squid fishing grounds in the Gulf roughly coincide with those of grounds in the sea off Japan[9].

Anchovy purse seine fishery is also a major fishery in this region. The fishing operation areas were found around Samet and Man Nok Islands, and the catch was sold to the fish sauce factories at Ban Phe in Rayong Province.

SUMMARY

This paper discusses the oceanographic conditions in the coastal waters off Rayong Province, Thailand, based on the data collected during the survey from 15 to 21 October 1984. The details of the discussion can be summed up as follows:

(1) The central depression of the Gulf was separated from the coastal waters off Rayong Province by a ridge at a depth of 16 metres.

(2) The distribution of fine calcareous biogenic remains in the sediments were concentrated in the steeper slope zone between 16 to 22 metres in depth.

(3) The grain size distribution of sediment in the waters falls roughly into two grounds separated by the 22 metres depth contour. One is the sandy area extending shoreward from the contour. Its configuration was irregular. The other is the muddy area in the depression deeper than 22 metres. Its configuration was flat. The sandy area could be further subdivided into two groups: one was a calcareous sandy area and the other was a sandy area, according to the calcium carbonate content of the samples. The narrow transition zone between the sandy coastal and the muddy depression areas were occupied by the calcareous sandy sediments.

(4) We could determine that each type of sediment distribution in the sea was characterized by the hydrodynamic conditions.

(5) It seemed that the five metres depth, in the waters off Ban Phe, indicated the limited depth of wave disturbance on the bottom from the point of new of hydrodynamics.

(6) A considerably high current velocity occurred in the surface layer around Man Nai Island during the period of low tide. The direction of the current changed frequently in 24 hours and no dominant direction could be found. This indicated that the observation area was in waters with eddies.

(7) We observed a certain phase of the collision of water masses with different salinities. One was a high salinity oceanic water mass originating from the South China Sea and the other was a low salinity coastal water mass.

(8) The oceanographic structure determining the squid fishing grounds in these waters; has the following features:

(a) Depth is 15 to 30 metres for squid;

(b) Bottom topography is steeper slope zone;

(c) Bottom sediment along the coast consists of abundant fine calcareous biogenic remains;

(d) Squid is attracted to the stagnant waters or eddies.

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We are grateful to Dr. Veravat Hongskul, Secretary-General, and Mr. Kazuo Inoue, Deputy Secretary-General of SEAFDEC, for their guidance and usuful suggestions.

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Tables

Table 2. Current measurement records at a depth of 2 metres off Man Nai Island (October 1984)

Time	Direction	Speed (cm/sec)	Component N	E
0800	52	11	6.776	8.668
0900	327	8	6.712	-4.360
1000	324	6	4.854	-3.528
1100	275	7	0.609	-6.972
1200	299	8	3.880	-7.000
1300	258	7	-1.456	-6.846
1400	68	9	3.375	8.343
1500	16	9	8.649	2.484
1600	351	12	11.856	-1.872
1700	56	11	6.149	9.119
1800	15	11	10.626	2.849
1900	310	12	7.716	-9.192
2000	336	11	10.054	-4.477
2100	164	14	-13.454	3.864
2200	191	15	-14.730	-2.865
2300	241	16	-7.760	-14.000
2400	149	21	-17.997	10.815
0100	175	18	-17.928	1.566
0200	253	20	-5.840	-19.120
0300	19	18	17.028	5.868
0400	250	17	-5.814	-15.980
0500	32	17	14.416	9.010
0600	9	15	14.820	2.340
0700	315	18	12.726	-12.726

Table 3. Ignited loss (%) of sediment samples in the waters off Rayong Province, 15-21 October 1984

St.No.	550°C(1 hr.)	950°C(1 hr.)	$CaCO_3$((2) ÷ 0.44)
1	1.57	3.69	8.39
2	3.63	8.91	20.25
3	2.82	10.38	23.58
4	2.29	10.12	23.01
5	4.40	26.45	60.12
6	11.96	22.41	50.93
7	3.14	33.18	75.42
8	6.81	15.87	36.07
9	2.68	11.08	25.18
10	2.10	5.13	11.67
11	7.41	12.84	29.18
12	5.13	20.75	47.17
13	4.54	28.99	65.88
14	4.36	18.75	42.62
15	3.98	19.23	43.70
16	5.22	18.54	42.14
17	8.95	6.18	14.05
18	7.61	8.09	18.40
19	5.17	26.07	59.26
20	3.84	24.91	56.61
21	4.94	27.43	62.33
22	4.60	27.60	62.73
23	10.56	6.88	15.63
24	9.14	5.23	11.89
25	9.62	6.42	14.60
26	9.35	7.38	16.77
27	6.10	22.88	52.01
28	4.77	24.74	56.22

Table 4. The ratio (%) of sand and mud in the sediments of the survey area off Rayong Province, 15-21 October 1984.

St.No. \ Size (mm)	<0.05	0.05-0.20	0.20-0.40	0.40-0.80	0.80-3.00	>3.00
1	40.31	11.24	28.84	9.98	8.49	1.14
2	30.07	20.91	9.69	7.13	17.25	14.96
3	53.41	11.71	9.46	8.41	11.29	5.72
4	32.00	23.99	17.69	8.50	11.65	6.17
5	12.30	14.10	12.86	4.96	13.48	42.30
6	21.08	20.87	11.91	9.70	18.90	17.55
7	22.91	22.80	7.41	6.58	17.42	22.89
8	28.60	20.06	18.24	6.38	18.42	8.30
9	13.84	31.05	20.10	10.57	17.27	7.17
10	12.64	43.24	19.74	3.13	11.03	10.25
11	69.25	13.44	6.70	4.07	4.98	1.56
12	47.18	4.71	8.72	7.94	14.03	17.42
13	27.40	18.36	9.25	6.41	14.52	24.06
14	22.67	14.68	19.18	10.60	17.12	15.75
15	42.07	14.36	10.76	6.08	12.42	14.31
16	40.08	15.05	9.51	9.70	16.86	8.80
17	63.32	25.87	4.55	3.13	2.84	0.29
18	43.51	34.63	12.55	3.90	4.11	1.30
19	31.49	14.98	7.27	8.01	18.68	19.57
20	11.16	16.41	20.61	9.40	17.71	24.71
21	37.45	11.94	6.36	5.73	16.79	21.74
22	38.03	9.32	3.55	5.68	18.81	24.61
23	61.57	14.90	20.22	2.74	0.33	0.24
24	79.23	16.34	1.13	1.20	1.83	0.28
25	80.65	16.59	1.38	0.69	0.69	-
26	80.85	16.64	1.55	1.74	3.48	1.74
27	69.26	19.21	1.58	0.45	4.52	4.97
28	39.13	18.38	2.56	3.92	12.81	23.20

< 0.05 : Mud

> 0.05 : Sand

Table 5. Tide table

October 1984

Date	Hours 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	Height of water in decimetres																							
15	10	9	9	10	13	16	20	23	25	27	28	28	27	26	25	24	24	23	23	22	20	18	15	13
16	10	8	7	8	10	13	17	21	24	26	28	28	28	28	27	26	26	25	24	23	22	20	17	14
17	11	8	7	7	8	10	14	18	21	24	27	28	29	29	28	28	27	26	26	25	24	21	19	16
18	12	9	7	6	7	8	11	15	18	22	25	27	28	28	28	28	28	27	27	26	25	23	21	18
19	15	12	9	7	7	8	9	12	16	19	22	24	26	27	28	28	28	28	27	27	26	25	23	20
20	18	15	12	10	9	8	9	11	14	16	19	22	24	26	26	27	27	27	27	26	26	25	24	22

Heights of water predicted in decimetres above the lowest low water. (Source : The meteorological Dept., Thailand)

Table 6. Sea water conditions in the waters off Rayong Province, 15-21 October 1984

St.No.	Depth(m)	Salinity(‰)	Temperature (°C)	Transparency (m)	DO (ml/L)
	0	32.805	29.49	8.0	4.912
1	5	32.805	29.50		4.884
	10	33.158	29.50		4.778
	14	33.214	29.42		4.662
	0	32.437	29.53	-	4.407
2	5	32.825	29.70		4.329
	10	33.019	29.48		4.387
	15	33.135	29.48		4.408
	0	33.045	29.50	8.0	4.200
3	5	33.109	29.50		4.205
	10	33.483	29.65		3.900
	15	33.524	29.47		3.898
	0	33.074	30.03	13.0	4.552
4	5	33.056	29.52		4.301
	10	33.065	29.47		4.273
	13	33.416	29.79		4.211
	0	32.829	29.61	11.0	4.233
	5	32.868	29.43		4.370
5	10	32.891	29.26		4.107
	15	32.930	29.24		3.954
	20	32.929	29.24		4.072
	25	32.920	29.30		3.865
	0	32.775	29.39	12.0	4.467
	5	32.787	29.28		4.337
6	10	32.828	29.27		4.307
	15	32.942	29.25		3.807
	19	32.981	29.25		3.844
	0	32.589	29.26	13.5	Broken
	5	32.735	29.25		4.326
7	10	33.160	29.26		4.342
	15	32.959	29.28		4.275
	18	32.631	29.30		4.212
	0	33.277	29.85	11.0	4.405
	5	33.287	29.65		4.425
8	10	33.319	29.35		4.340
	15	33.529	29.28		4.186
	18	33.296	29.30		4.236

Table 6. (cont'd)

St.No.	Depth(m)	Salinity(%o)	Temperature (^oC)	Transparency (m)	DO (ml/L)
	0	33.218	29.97	–	4.422
	5	33.217	29.78		4.417
9	10	33.182	29.39		4.308
	15	33.435	29.51		4.420
	17	33.406	29.40		4.201
	0	32.161	30.36	–	4.313
10	5	32.730	29.78		4.586
	10	33.173	29.78		4.030
	0	32.496	29.25	12.0	4.523
	5	32.483	29.07		4.477
	10	32.474	29.00		4.540
11	15	32.491	28.95		4.398
	20	32.970	29.02		4.093
	25	32.963	29.05		3.734
	30	32.991	29.10		3.821
	0	32.872	29.19	14.0	4.457
	5	32.874	29.18		4.373
12	10	32.604	29.02		4.471
	15	32.893	29.02		4.501
	20	33.226	28.99		3.947
	25	32.980	29.03		3.632
	28	33.243	28.98		3.641
	0	32.673	29.04	16.0	4.512
	5	32.652	29.04		4.271
	10	32.908	29.05		4.322
13	15	32.731	29.05		4.394
	20	32.982	29.07		3.740
	25	33.243	28.98		3.587
	0	32.865	29.31	15.0	4.353
	5	32.849	29.29		4.435
	10	32.909	29.30		4.296
14	15	33.110	29.29		4.272
	20	32.963	29.18		3.865
	23	32.959	29.10		3.839
	0	33.050	29.31	15.0	2.923
	5	33.047	29.26		4.453
15	10	33.054	29.22		4.503
	15	33.042	29.30		4.370
	20	33.132	29.25		4.010

Table 6. (cont'd)

St.No.	Depth(m)	Salinity(‰)	Temperature (°C)	Transparency (m)	DO (ml/L)
	0	32.364	29.60	14.0	4.521
	5	32.438	29.26		4.735
16	10	32.881	29.61		4.181
	15	33.140	29.54		4.243
	19	33.147	29.46		4.165
	0	32.187	28.71	21.0	4.601
	5	32.202	28.75		4.802
	10	32.400	28.86		4.683
17	15	32.803	29.04		4.676
	20	33.234	28.99		3.937
	25	33.233	29.04		4.076
	29	33.230	28.89		4.022
	0	32.144	28.76	24.0	4.720
	5	32.155	28.75		4.833
	10	32.454	28.88		4.377
18	15	32.780	29.10		4.735
	20	33.230	29.03		4.062
	25	33.246	29.01		3.994
	30	33.248	28.95		3.925
	0	32.353	28.82	21.0	4.690
	5	32.557	28.92		Broken
	10	32.748	29.00		4.700
19	15	32.846	29.00		4.433
	20	32.901	29.06		4.735
	25	33.237	29.02		3.649
	29	33.239	28.94		3.737
	0	32.964	29.26	20.0	4.856
	5	32.989	29.25		4.548
20	10	32.988	29.24		4.486
	15	32.996	29.24		4.524
	20	33.066	29.34		4.483
	27	33.237	28.99		3.959
	0	32.374	29.20	18.0	4.797
	5	32.438	29.04		4.486
21	10	32.910	29.26		4.334
	15	33.026	29.24		4.419
	20	33.146	29.23		4.316
	25	33.148	29.15		4.153

Table 6. (cont'd)

St.No.	Depth(m)	Salinity(‰)	Temperature (^oC)	Transparency (m)	DO (ml/L)
22	0	32.492	29.38	14.0	4.389
	5	32.493	29.45		4.530
	10	32.637	29.36		4.626
	15	33.193	29.22		4.244
	20	33.207	29.18		4.588
23	0	32.246	29.00	22.0	4.565
	5	32.236	28.89		4.705
	10	32.017	28.89		4.616
	15	31.955	28.86		4.790
	20	32.328	29.13		4.760
	25	32.773	28.90		4.572
	30	32.611	28.98		4.662
	35	32.974	28.85		4.152
24	0	32.553	-	22.0	4.509
	5	32.236	28.94		4.941
	10	32.548	28.89		4.969
	15	32.652	28.91		4.697
	20	33.447	29.12		4.759
	25	33.636	28.96		4.195
	30	33.668	28.89		3.986
	33	33.344	28.80		4.175
25	0	32.674	29.06	19.0	4.678
	5	33.214	29.08		4.475
	10	32.759	29.04		4.584
	15	33.196	29.05		4.682
	20	32.930	29.06		4.566
	25	32.885	29.14		4.494
	31	33.266	28.87		3.690
26	0	32.770	29.01	17.0	4.554
	5	32.670	29.01		4.649
	10	32.636	28.97		4.573
	15	33.150	29.07		4.490
	20	33.042	29.17		4.454
	25	33.471	29.16		4.137
	32	33.169	28.89		4.085

Table 6. (cont'd)

St.No.	Depth(m)	Salinity(‰)	Temperature (^oC)	Transparency (m)	DO (ml/L)
	0	32.711	29.17	19.0	4.496
	5	33.015	29.14		4.478
	10	32.710	29.08		4.383
27	15	32.991	29.16		4.556
	20	33.100	28.94		3.815
	25	33.623	29.00		3.727
	27	33.266	28.94		3.835
	0	32.701	29.28	18.0	4.574
	5	32.955	29.25		4.455
28	10	32.921	29.19		4.553
	15	32.998	29.16		4.559
	20	33.275	29.10		4.376
	25	32.969	29.02		4.609

Table 7. Nutrient salts in the waters off Rayong Province, 15-21 October 1984

St.No.	Depth(m)	Phosphate-P (ug-at/L)	Silicate-Si (ug-at/L)	Sub-Si (ug-at/L)	Nitrite-N (ug-at/L)	Nitrate-N (ug-at/L)	Ammonia-N (ug-at/L)
1	0	0.20	13	11	ND	ND	ND
	10	0.10	15	12	ND	ND	ND
	14	0.10	14	11	ND	ND	0.55
2	0	0.10	19	17	ND	ND	ND
	10	0.26	13	11	ND	0.05	0.59
	15	0.10	15	13	ND	ND	0.35
3	0	1.46	19	17	ND	ND	0.14
	10	0.20	25	22	ND	ND	0.16
	15	0.04	20	18	ND	ND	0.18
4	0	0.16	14	12	ND	ND	0.13
	12	0.04	12	10	ND	ND	0.16
5	0	0.20	2	3	ND	ND	ND
	10	0.10	13	11	ND	ND	ND
	20	0.16	7	7	.045	ND	0.03
	25	0.20	5	5	ND	ND	0.03
6	0	0.10	6	6	ND	0.16	ND
	10	0.10	10	9	ND	ND	ND
	19	0.10	8	8	ND	ND	ND
7	0	0.38	5	5	ND	ND	ND
	10	0.10	ND	ND	ND	ND	ND
	18	0.10	2	2	ND	ND	ND
8	0	0.10	12	10	ND	ND	0.16
	10	0.10	12	10	.045	ND	0.29
	18	0.10	ND	ND	ND	ND	0.16
9	0	0.16	12	10	ND	ND	0.13
	10	0.20	13	11	ND	ND	0.10
	17	0.04	10	9	ND	ND	ND
10	0	0.42	24	21	ND	ND	0.19
	10	0.38	22	19	ND	ND	0.10
11	0	0.10	12	10	ND	ND	ND
	10	0.10	5	5	ND	ND	ND
	20	ND	21	18	ND	ND	ND
	30	0.26	5	5	ND	ND	ND

ND : below limit of detection

Table 7. (cont'd)

St.No.	Depth(m)	Phosphate-P (ug-at/L)	Silicate-Si (ug-at/L)	Sub-Si (ug-at/L)	Nitrite-N (ug-at/L)	Nitrate-N (ug-at/L)	Ammonia-N (ug-at/L)
12	0	0.04	1	2	0.07	ND	0.05
	10	0.04	6	6	ND	ND	0.55
	20	0.32	13	11	ND	ND	0.29
	28	0.20	17	15	ND	ND	7.00
13	0	0.04	13	11	0.07	ND	ND
	10	ND	11	9	ND	ND	ND
	20	0.38	15	13	ND	ND	ND
	25	0.32	18	15	ND	ND	0.09
14	0	0.16	11	10	ND	ND	0.05
	10	0.20	10	9	ND	ND	0.13
	22	0.16	11	10	ND	ND	ND
15	0	0.10	7	7	ND	ND	0.14
	10	0.04	13	11	ND	ND	0.29
	20	0.38	11	10	ND	ND	0.06
16	0	ND	23	20	ND	ND	0.27
	10	ND	25	22	ND	ND	0.82
	18	ND	24	21	ND	ND	0.32
17	0	0.10	8	8	ND	ND	0.18
	10	0.16	9	8	ND	ND	0.16
	20	ND	12	10	ND	ND	0.55
	29	ND	18	16	.045	ND	ND
18	0	0.20	10	9	ND	ND	0.55
	10	ND	10	9	ND	ND	0.14
	20	ND	15	13	ND	ND	1.05
	30	ND	15	13	.045	ND	0.59
19	0	0.74	8	7	ND	ND	0.68
	10	ND	11	10	ND	ND	0.41
	20	ND	11	10	ND	ND	0.55
	29	0.10	21	19	.155	ND	0.55
20	0	ND	24	21	.155	ND	0.41
	10	0.38	21	19	ND	ND	0.09
	20	ND	20	18	ND	ND	0.05
	27	ND	26	23	ND	ND	1.09
21	0	ND	21	18	ND	ND	0.45
	10	ND	23	20	ND	ND	0.14
	20	ND	23	20	ND	ND	ND
	25	0.20	22	18	ND	ND	0.59

Table 7. (cont'd)

St.No.	Depth(m)	Phosphate-P (ug-at/L)	Silicate-Si (ug-at/L)	Sub-Si (ug-at/L)	Nitrite-N (ug-at/L)	Nitrate-N (ug-at/L)	Ammonia-N (ug-at/L)
22	0	ND	17	15	ND	ND	0.05
	10	ND	24	20	ND	ND	0.27
	22	ND	13	11	ND	ND	0.09
23	0	0.42	4	4	ND	ND	0.09
	10	0.10	18	16	.025	ND	ND
	20	ND	5	5	ND	ND	0.27
	32	ND	14	12	ND	.025	0.32
24	0	0.26	5	5	.355	ND	0.10
	10	0.10	16	9	ND	ND	0.06
	20	0.04	6	5	ND	ND	0.23
	32	0.16	16	14	ND	ND	0.13
25	0	0.04	6	6	.310	ND	0.10
	10	0.04	2	3	ND	ND	ND
	20	0.10	8	8	ND	ND	0.13
	31	0.26	19	17	ND	ND	0.10
26	0	0.32	22	19	ND	ND	0.26
	10	0.10	19	17	ND	ND	ND
	20	0.10	19	17	ND	ND	0.06
	32	0.16	14	12	ND	ND	0.36
27	0	0.38	8	8	ND	ND	ND
	10	0.04	19	17	ND	ND	0.13
	20	0.04	16	14	ND	ND	ND
	27	0.10	26	22	ND	ND	ND
28	0	0.32	17	15	ND	ND	0.29
	10	1.44	20	18	ND	ND	ND
	20	0.10	11	10	ND	ND	0.16
	25	0.10	16	14	ND	ND	0.29

Table 8. Chlorophyll-a (μg/L) in the waters off Rayong Province, 15-21 October 1984

Station No.	Chlorophyll-a
1	0.5094
2	0.6705
3	0.5094
4	0.3665
5	1.4600
6	0.5690
7	0.3990
8	0.5010
9	0.3395
10	1.4605
11	0.3310
12	0.2210
13	0.2285
14	0.4415
15	0.3985
16	0.2210
17	0.1780
18	0.2285
19	0.2720
20	0.2285
21	0.2290
22	0.4575
23	0.1700
24	0.1695
25	0.2800
26	0.2800
27	0.2205
28	0.2720