PHYSICAL AND CHEMICAL OCEANOGRAPHIC ASPECTS 
IN A CHICOREUS RAMOSUS FISHING GROUND 
IN THE ANDAMAN SEA, THAILAND

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INTRODUCTION

In the First Workshop of Tropical Marine Mollusc Programme, some biological, chemical and physical aspects of the Southern Andaman Sea were reviewed. It was shown that this area had a very high production and fishery potential (Khokkiantiwong 1991). In regard of ecology and fishery of Chicoreus ramosus, it was found that C. ramosus occurred at most islands located along the shore-line of southern Phuket to Satun province. The most popular fishing grounds of this snail were in the area between south-southeast of Talibong and Phetra Islands (Fig.1). Many studies have indicated that this area is the most productive area of the southern Andaman Sea coast of Thailand (Chatananthewej and Bussaranwit 1987, Janekarn and Hylleberg 1989, and Limpsaichol et al. 1991). This area therefore has many fishery activities not only for C. ramosus but also for squid, mackerel, and other molluscs.

Many ecological and biological studies of C. ramosus are presented in these proceedings but information is rather limited regarding environmental and oceanographic parameters which are important in terms of controlling distribution and abundance of C. ramosus. If we could combine this knowledge with other studies in TMMP we might be able to make a model leading to more understanding of the ecology and biology of C. ramosus. Such knowledge would be useful for sea farming and fishery management of C. ramosus in the future.

The purpose of this study is therefore to investigate the extent of environmental and oceanographic parameters that influence the abundance and distribution of C. ramosus.

MATERIALS AND METHODS

Study Site

The survey was carried out by research vessel No. 10 of Andaman Sea Fisheries Development Center during the northeast monsoon, February 1992 at the peak of C. ramosus fishing. The investigation comprised an oceanographic team, a C. ramosus survey team, and a diving team working together. Suitable periods of these surveys were during neap tide of the northeast monsoon with calm weather, clear water and weak current.

I selected the area between southeast to south of Ko Talibong and Ko Ta-bai as the study site, because of its popular fishing ground with abundance of C. ramosus (area I, Fig.2). The area between north of Ko Talibong and south of Ko Lanta were selected as reference site (area II, Fig.2), because the survey along the coast of the Andaman Sea indicated that the area II had low abundance of C. ramosus when compared to area I. Both areas are shallow as most water depths are not more than 10 metres. Sandy beaches, mangal areas, and seagrass beds are found along the shore-line. In area I, there is more freshwater runoff from many tributaries, canals, and rivers. Seagrass beds are quite important to the coastal ecological system providing nursery grounds of marine organisms. The biggest seagrass bed, two kilometres wide, is located in front of the village of Ko Talibong, in area I (Fig.2; Poovachiranon, personal contact). There are also many small islands with submerged rocks in these areas, especially in area I.
Water Sampling

A total of 42 stations were investigated, 25 stations (st.1-st.25) and 17 stations (st.26-st.42) located in area I and area II (Fig.2) respectively. Nine parameters were measured and analyzed. Salinity, oxygen, temperature, transparency, and pH were measured directly on the vessel. Some water samples were processed and preserved prior to analysis in the laboratory of the PMBC (salinity, phosphate, nitrate, nitrite, and total suspended solid). The methods employed for each parameter are shown in Table 1. Only salinity was analyzed by two methods, both direct measurement (salinometer; Bridge Type M.C.5) and chemical measurement (for salinometer calibration). All parameters were measured at three depths, viz. surface level: 1 metre below the surface, mid level: the middle of total depth which depends on the depth of each station, and bottom level, 1 metre above the sea bottom.

A line transect of salinity and temperature was recorded for salinity and temperature profile interpolation in area I. There were eight sampling stations along the transect (Fig.2). Both salinity and temperature were measured every two metres consecutively from 1 meter below the sea surface to 1 meter above the sea bottom.
Figure 2. Study area I & II, sampling stations (●), and line transect (a-b; for temperature-salinity profile study).

Table 1. Sea water analysis methods employed in this study.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Technique employed</th>
<th>Instrument</th>
<th>Reference</th>
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<tbody>
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<td>Salinometer</td>
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<td>GF/C filtration</td>
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Sediments Sampling

Sediment was sampled by a Van Veen grab at the water sampling stations just after water sampling. Sediments were frozen prior to analysis at the PMBC laboratory. The three main factors; grain size distribution, dry bulk density, and percentage of organic content, were determined.

Grain size analysis was done by the method of Holme and McIntire (1984), wet sieving method. The mesh size series of the sieves were 2, 1, 0.5, 0.25, 0.125, and 0.063 mm. The moments method of analyzing grain size distribution was employed to analyze these data (McManus 1988, Deborah et al. 1991). The formulae for the first moment (mean) and second moment (standard deviation or sorting level) are as follows:

\[
\text{Mean (first moment): } X = \frac{\Sigma f m\phi}{100}
\]

\[
\text{Standard Deviation } \sigma^2 = \frac{\Sigma f (m\phi - X)^2}{100}
\]

where \(f\) is the percentage fraction in each class interval of the total weight of sediment and \(m\) is the mid-point interval of each class interval in phi units.

Organic content analysis was carried out on the dried sediments which were ashed at 550 °C for 4 hrs and reweighed. The weight loss represents the organic content expressed as a percentage of dry weight.

The hardness of the sea bottom was indicated by dry bulk density value (Deborah et al. 1991). The dry bulk density calculation is as follows:

\[
\text{Dry Bulk Density} = \frac{\text{Mass of Dry Sediment}}{(\text{Mass of Dry Sed}./2.45) + (\text{Mass of Water}/1.02)}
\]

The average density of the sediment is taken as 2.45 g cm\(^{-3}\) and the density of sea water is taken as 1.02 g cm\(^{-3}\). The compactness of sea bottom sediment (hardness) increases with the dry bulk density value.

RESULTS

Water Parameters

Some parameters of this study were compared with data of five years study (1982-1986) from the southern coast of Andaman Sea, as shown in Table 2. There were some differences between these two data sets when divided into group I comprising salinity, phosphate, nitrite, and nitrate and group II comprising total suspended solids and temperature. It was found that the values of group I were lower than the present values, whilst the values of group II were higher. It might be caused by the annual weather variation, such as temperature which increased along this shoreline in 1990 and 1991 during summer. Temperature as high as 31°C was recorded with dramatic changes in rainfall in some years, etc. However, such variations were regarded to be normal on the Andaman Sea Coast of Thailand (Nipawan et al. 1985, Jane-karn and Hylleberg 1989, National Environmental Board 1989, and Prawin et al. 1991).

The values of each parameter of area I compared to II shown in Table 3 were not significantly different in most parameters, except pH and transparency (both t-test and ANOVA, \(P < 0.05\)). However the pH values appeared slightly different in these two areas.

The horizontal distribution of some oceanographic parameters are shown in Figures 1-5. The salinity distribution was found to display high variation in the upper layer particularly around islands (Fig.3a). Low salinity (\(<31.0\) ppt) water masses were recorded in the upper layer on the southeast side of Ko Talibong, Ko Liang-nua and Ko Liang-tai. In the
lower layer, high salinity water mass about 32 ppt intrudes into the coastal area (Fig. 3b). Generally, patterns of salinity over these areas increased from near-shore to offshore and from surface to bottom as the pattern found in Phangnga Bay, upper south of Andaman Sea of Thailand (Khokiatitwong et al. 1991).

The distribution of total suspended solids (TSS) was found similar in both area I and II except on the southeast side of Ko Talibong, which had the lowest TSS (Fig. 4a). Transparency of area II was higher than the values in area I. The lowest transparency also occurred on the southeast side of Ko Talibong (Fig. 4b). Lower transparency of area I, especially on the southeast side of Ko Talibong, might be caused by high content of fine sediment (silt-clay) dispersing in the water column. Fine sediment is considered to originate from riverine runoff.
Figures 3a-b. The distribution of salinity in study area (a) upper water layer, (b) lower water layer.

However, fine sediment did not have much effect on TSS as it contributed little to the total weight. The distribution of nutrients (nitrate, nitrite, and phosphate) tended to give higher values in area I than area II, although it was not significantly different in statistic tests (ANOVA and t-test, P > 0.05), as there are more runoff from many tributaries and cannels in area I, especially on the southeast side of Ko Talibong and it was found that the water mass contained high nutrient concentrations (Figs.5a-c).

Figures 4a-b. The distribution of (a) total suspended solid and (b) transparency in study area.

The profile of salinity along transect a and b (Fig.2) shows high salinity water (>32 ppt) from offshore intruding the coastal area as a bottom water layer (Fig.3b). At the surface, low
Figures 5a-c. The distribution of nutrients in the sea water of study area: (a) nitrate, (b) nitrite, and (c) phosphate.

Salinity water mass occurred at 3, 6, and 9 nautical miles along the transect from shore to offshore (Fig. 6a). It was also found that there were high temperature water masses at the surface layer. At 2 to 3 nautical miles on the transect, the water temperature might be a result of the shearing point of these two water masses (Fig. 6b).

Sediment Compositions

Comparisons of sediments from the two areas are shown in Table 2 and 3. Only mean grain size showed significant difference between those two areas. Based on the Wentworth Grade Classification (McIntyre 1984) the substrates of area I and II were fine and very fine sand
Figures 6a-b. The vertical distribution of (a) salinity and (b) temperature along the line transect of area I.

respectively. The horizontal distribution of mean grain size is shown in Figure 7b. Most of the mean grain size values of area I were 2 to <2 phi, except offshore, while area II had values higher than 3 to <2 phi (Fig. 7b). The dry bulk density of sediments did not show significant difference in statistic tests but as shown in Figure 7a most of area I had values of more than 1.4 g l⁻¹ while in area II, half of the area on the offshore side was lower than 1.4 g l⁻¹. Degree of sorting of the two areas was not significantly different in statistical test but the horizontal distribution displayed a trend of higher values in area I than in area II (Fig. 8a). The organic content in the two areas did not show any statistically significant difference (Fig. 8b).

Figures 7a-b. The distribution of (a) dry bulk density and (b) mean grain size (phi units) of sea bottom sediments in study area.

The relationships of mean grain size, sorting value (standard deviation), and percentage of organic content show that the increment of organic content increases with standard deviation (sorting value) and mean grain size (phi; Fig. 9).
Figures 8a-b. The distribution of (a) degree of sorting and (b) percentage of organic content of sea bottom sediments in study area.

Figure 9. The relationships among mean grain size (phi units), degree of sorting (standard deviation), and percentage of organic content of sea bottom sediments in study area.

Figure 10. The model of frontal eddy formation on the southeast coast of Ko Talibong.
DISCUSSION

Water Parameters

Salinity is a very important parameter which limits distribution of marine organism in each area. The nearshore salinity was higher than 30 ppt which may be due to the low runoff from rivers during this period of the dry season. Salinity was therefore not a limiting factor for marine organism living close to shore, including *Chicoreus ramosus*. TMMP’s survey team found that *C. ramosus* was distributed between offshore to very nearshore localities, even on the east side of Ko Talibong which is close to a river mouth. In the rainy season, low salinity water (<30 ppt) may extend over shallow areas, especially in area I where fishing grounds and abundance of *C. ramosus* are found. It has been suggested that *C. ramosus* might move to deeper water, a bit far from shore. Unfortunately there are no data during raining season of these areas to support this aspect.

From statistical tests of all parameters, only pH and transparency were slightly different between area I and II. Transparency of the more shallow area I was lower than area II. In area I, sunlight however could penetrate into the water column similar to area II. Light, therefore could not be regarded as a limiting factor for photosynthesis of phytoplankton, in area I. PH of area I was slightly higher than area II and was significantly different (P<0.05). Since area I received more runoff the pH should be lower than area II. It might be possible that area I had a higher primary production than area II. Photosynthesis may characterize the buffering effect of sea water in such a way that increase of photosynthesis will increase pH. It implies that area I might have higher primary production than area II. Unfortunately we did not do any primary production study when cruising. Janekarn and Hylleberg (1989) studied primary production in 1982-1983 and found that area I had higher primary production than area II but there was some variation between years as also found in a plankton biomass study (Boonruang 1987).

It could be possible that there were some physical mechanism supporting primary production enhancement in area I. The circulation of currents in these areas were studied by Khokiatiwong (1991) who suggested that an eddy circulation should characterize the southeast side of Ko Talibong. The distribution pattern of each parameter in this study (Figs. 3-6) showed that there was a water mass which had low salinity, total suspended solids, and transparency, but had high nutrient concentrations and temperature (compared to ambient water) on the southeast side of Ko Talibong. The characteristics of this water mass indicated a good primary production potential even if there was low transparency as discussed above. This water mass was formed by mixing of coastal water which was influenced by runoff, high nutrients, and offshore water. The formation of this water mass might be similar to a frontal eddy (Fig.10). During flood tide, salinity and temperature were measured along the line transect, the offshore surface current (high salinity) intruded the coast south of Ko Talibong (Khokiatiwong 1986, 1991). When the current was close to southeast of Ko Talibong, it would change direction to eastward. This eastward current might again shear the coastal water (low salinity) and then form the frontal eddy on the southeast side of Ko Talibong (Fig.10; Khokiatiwong 1986, 1991). The eddy which had high nutrient concentrations would have high primary production and zooplankton production (Sanders 1971), as nutrients could be associated with the water mass longer than normal before dispersing. Nutrients were therefore available for longer periods of utilization by phytoplankton. At ebb tide, the frontal eddy would stop forming and move offshore with ebb tide current passing Ko Liang Nua and Liang Tai and slowly disperse into ambient waters of low salinity water mass at a distance of 6 to 9 nautical miles (Figure 6a). This mechanism would help to support nutrients from the coast to the offshore of area I. The southeast side of Ko Talibong is therefore a very productive area. This includes the biggest seagrass bed located in southern Andaman Sea coast.
It is concluded that water quality of the two areas did not differ much. But area I had some physical mechanisms supporting primary production enhancement (frontal eddy) and marine organisms aggregated in this area especially on the southeast section of Ko Talibong.

**Sediment Composition**

The distribution pattern of dry bulk density, degree of sorting, and percentage of organic content seem to be different between area I and II, but statistic tests did not show significant differences. It may be due to a small number of samples in each area (25 and 17 stations in area I and II respectively). Some measurements indicated high variation leading to no difference in statistic tests.

The difference of mean grain size (phi) between the two areas (see Table 4) indicate that the sea bottom sediment of area II is much finer and softer than in area I. Observations during sediment sampling also indicated that the west side of area II had a mean grain size and dry bulk density less than 3 phi and 1.4 g l⁻¹. It therefore should be classified as mud to muddy sand substrate. It was a soft bottom with a high organic content (Figs. 7a-b). The sediment tends to have high organic content when there was small mean grain size and poor degree of sorting (Fig.9). The sea bottom of area I was more sandy than area II as area I is more shallow causing the fine sediments to be swifted out by tidal currents which impose a high influence on these areas (Khokiattiwong 1991; Mann and Lazer 1991).

The substrate has more influence on abundance and distribution of *Chicoreus ramosus* than water quality of these areas. The abundance of *C. ramosus* should be correlated with the number of other benthic organisms serving as food source. Chatanathaweij and Bussarawit (1987) showed that the number of benthic organisms tends to decrease with increase of organic content and mean grain size (phi), though it was not obvious. In a substrate selection experiment with coarse sand, fine sand, coral fraction, and mud substrates the *C. ramosus* distributed in all substrates except in the mud. After a few weeks, when some coarse sand and fine sand became mixed into the mud substrate, some of them distributed into this new substrate but very few (Thapnu, unpublished data). The mud substrate of soft bottom might be difficult for snails to move about. It is therefore possible that area I might have a substrate which is suitable for *C. ramosus* since there is abundance of food and not too soft substrate. That might be the reason why there was a higher abundance of *C. ramosus* in area I than area II.

Many small islands around Phuket have fishing grounds for *C. ramosus* although not with an abundance of snails as in area I. Most bottom sediments around those islands are composed of fractions of coral or sandy substrate. The inner port of Phang-nga Bay, which is located northeast of Phuket, is not a fishing ground of *C. ramosus*. But many small islands at the mouth of the Phang-nga Bay serve as fishing grounds of *C. ramosus*. It may be due to the bottom of the Bay which is soft bottom, mud, sandy mud, and muddy sand (Carr *et al.* 1991) as the area II.

**Relationships between Environmental Parameters and *Chicoreus ramosus***

The main fishing ground of *C. ramosus*, area I, is not a big area but there is a very heavy fishing pressure during northeast monsoon when the sea is calm and clear. The fishing method is exclusively diving but a large number of snails are collected each year and most of them are only big size. The collection is reported to have occurred for many decades. If the stock of *C. ramosus* remains only in this small area, then overfishing of the stock is expected and may eventually lead to destruction of the stock.

It might be possible that this snail has a migratory behavior. It migrates to coastal or shallow areas during spawning season, just before and after the southwest monsoon (infor-
mation obtained from fishermen). The coastal areas provide more food for snail larvae. Salinity is not too high (<32 ppt) and the density of water is on the low side. The veliger larvae can swim up and down searching for food in the water column. Settling on the sea bottom, at metamorphosis, is very easy as snail body density may be a bit higher or similar to density of seawater. In the deeper offshore water, salinity is comparatively high (>34 ppt) throughout the water column and there is low food concentrations for snail larvae. If we can measure the density of the snail body we will be able to explain more about this aspect. When snails migrate to coastal areas they apparently prefer very highly productive substrates which are also suitable for larval settlement. Steenfeldt and Bussarawit (1992, this volume) suggested that the survival rate of *C. ramosus* larva depends on food supply and type of substrate. After settling the larva might live in shallow water for a certain period of time before migrating to deeper water and scattering over suitable sea bottom. In the coastal areas with fishing grounds of small size, the number of snails will become dense and sometimes snails aggregate attaching to each other, like a small hill on the sea bottom. This aggregatory behaviour is still subject to speculation. It might be spawning behaviour as the snails need to attach the eggs on hard substrates. If they cannot find any hard substrates, they may attach egg capsules on shells of each other.

From the above it is realized that the fishermen can harvest or collect snails very easily, especially in areas which are very productive and have suitable substrates. This study indicates that the suitable substrate should be sandy to sandy mud. Since diving is the only fishing method for *C. ramosus*, water depths exceeding 15 m are limiting. It allows the small snail a chance to grow up to maturity and become big in deep water without being harvested before migration to the coast. This might be the reason that fishermen have been able to continue harvesting the snail for a long time within only a small area without collapse of the stock.

The morphology of *C. ramosus*, long spined and short spined form, is discussed in other contributions to this volume. It is suggested that the difference of long and short spined snails might be attributed to environmental factors. The hard substrate habitat (coral fraction or rocky bottom) and soft substrate harboured mostly short spined and long spined snails respectively.

Lyons (1979) found that the morphological difference of snails in some species of the family Muricidae was affected by water depth and habitats. If the migratory behavior of *C. ramosus* as discussed above is true, it may be possible that snails which migrate to deeper water will have a shape which differs from others staying only shallow water.

**SUMMARY**

1. *C. ramosus* was distributed in all types of substrate but rarely in muddy substrate. The species was most abundant within the highly productive areas with sandy or sandy muddy substrates.

2. *C. ramosus* might display spawning and feeding migratory behavior. It migrates to coastal areas during spawning season and larvae grow up in this area for a certain period of time before migrating to deeper water.

3. The difference of morphology may be attributed to variation in environmental factors. There are two factors: (a) type of substrate, short spined snails are mostly found in hard substrate and long spined in soft substrate (b) water depth may also affect spine lengths of snails.
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