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SPECIES COMPOSITION AND ABUNDANCE DISTRIBUTION
OF ANOMURAN SAND CRABS, AND POPULATION BIOMICS OF
EMERITA EMERITUS (L.) ALONG THE INDIAN OCEAN COAST OF THAILAND
(DECAPODA : HIPPIDAE)

by

Pensri Boonruang and Boonlert Phasuk

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ABSTRACT

Studies on species composition, distribution and abundance of the species of anomuran sand crabs were carried out on the exposed sandy beaches along the west coast of Thailand on the Andaman Sea. Three species, Emerita emeritus (L.), Hippa adactyla F., and Albunea symmetrica (L.), were collected in the area. E. emeritus was found to be the most abundant species. Fishing grounds, fishing technique and physical and chemical environment were also studied.

Detailed studies are made on the population dynamics of Emerita emeritus in relation to physical and chemical parameters. Data on size composition, sex ratio, growth rates, spawning seasons and length-weight relationship are analyzed. Tidal rhythmic activities and vertical distribution are also discussed.

I. INTRODUCTION

Anomuran sand crabs of the family Hippidae (superfamily Hippoidea) are represented, in the Indo-Pacific region, by three genera, namely Emerita (Scopoli, 1777), Hippa (F., 1787) and Mastigocheris (Mier, 1878). Species of the genus Emerita are known in Thailand as “Jakajan-talay”. This name probably arises from the remote resemblance of the animal to the cicada, which is called “Jakajan” in the Thai language; “talay” means sea. They are sometimes called “sea-grashoppers”, which we think is a misnomer because of the basic differences in structure and other features. They are occasionally also referred to as “mole crabs.” Species of the genus Hippa (along with those of Albunea of the family Albuneidae) are known as “Jakajan quai” in
Thailand, ("quai" means buffalo in the Thai language, probably referring to the comparatively large size of these species), but they are very rare.

Five species of the genus Emerita, namely E. emeritus (L., 1767), E. austroafricana (Schmitt, 1973), E. holthuisi (Sankolli, 1965), E. analoga (Stimpson, 1857) and E. rathbunea (Schmitt, 1935) have so far been reported from the Indo-Pacific region and their distribution has been studied by several investigators. Along the east coast of India, E. emeritus (= E. asiatica H. Milne Edwards) was recorded from Madras (Menon, 1934; Alikunhi, 1944) and Visakhapatam (Ganapathi and Rao, 1959). Schmitt (1937) collected E. austroafricana from Durban, South Africa. E. holthuisi was recorded along the west coast of India at Ratnagiri (Sankolli, 1965) and further south at Shertalai and Cochin along the Kerala coast (Ansell et al, 1972 a, b). All species were recorded as found on sandy beaches.

Efford (1967; 1970) found that E. analoga occurred in the wash zone of exposed sandy beaches along the temperate west coast of America from Kodiak Island in Alaska to Baja California and further south from Salaverry, south Peru to around False Bay, Argentina on the Atlantic coast. Efford (1967) also recorded E. rathbunea from the tropical zone in between, at Guerrero, Mexico.

E. emeritus was recorded in 1969 (Anonymous) from Phuket as Hippa asiatica. This is the only record so far of this genus from Thailand.

Twelve species of Hippa have been reported from the Indo-Pacific region but there is much confusion on the taxonomy of the species. Due to an earlier type-species designation, which was later proved to be invalid, all species of Emerita were wrongly assigned to Hippa, and the genus Hippa was in turn, called by the synonym Remipes (Latreille, 1804). The status of Hippa adactyla F., which is the only Hippa species dealt with in the present investigation presented a particular problem; this later was clarified by Haig (1970). Hippa adactyla is the type-species for the valid genus Hippa in the official list of Generic Names in Zoology (1963). This genus has not been previously recorded from Thailand.

Mastigocheirus, the third genus of the family Hippidae, has not been recorded from Thai waters and is therefore left out of the present discussions.

Family Albuneidae of the superfamily Hippoidea is represented by only one genus Albunea (F., 1798) and one species A. symnista (L.) in Thailand. This genus and species has not been previously recorded from this area.

The species of Emerita, Hippa and Albunea so far recorded from the Indo-Pacific region are listed below. Of these the three species recorded from Thai waters in the course of the present investigation are indicated by an asterisk.

Family Hippidae
Genus Emerita
E. analoga (Stimpson)
E. austroafricana Schmitt
E. emeritus (L.)*
E. holthuisi Sankolli
E. rathbunea Schmitt

Genus Hippa
H. adactyla F.*
H. admirabilis (Thallwitz)
H. celenensis (Thallwitz)
H. coelano (De Man)
H. denticulatifrons (White)
H. hirtipes (Dana)
H. marmoratus (White)
H. ovalis (A. Milne Edwards)
H. pictus (Heller)
H. pacifica (Dana)
H. truncatifrons (Miers)
H. strigillata (Stimpson)

Family Albuneidae
Genus Albunea
A. symnista (L.)*

In general, very little is known on the ecology and biology of anomuran sand crabs of the Indo-Pacific region. One of the investigations bearing specifically on this subject is that of Menon (1934),
who studied the habits and sexual characteristics of *Emerita (Hippaa) statica* (= *E. emeritus*). He found that a good number of males could be collected at the low water mark and they could easily be distinguished from the females by the presence of genital papillae on the coxopodites of the last pair of thoracic legs. He also found that the carapace length of the males ranged from 3.5 to 6.0 mm. and never more than 6.0 mm, while that of the adult females varied from 22.0 to 30.0 mm.

Alikunhi (1944) studied the zonal distribution of *E. emeritus*. He found that the smaller animals are found near the high water level while the larger animals occur near the low water level. This pattern of distribution appeared to be caused by the differences in the nature of the substratum. At the low water level, the substratum is composed of coarse grain sand and at the high water level, fine grain sand. He concluded that the distribution pattern of a species on a sandy beach could be influenced by various factors such as the nature of the substratum, period of exposure, availability of food, etc.

Ansell et al (1972 a, b) studied the ecology of *E. holthuisi* along the Indian coast. They found that there were two main periods of recruitment to the beach population, one in the pre-monsoon months of February and March and one during the monsoon months. Comparative studies of population densities are made difficult by their habit of tidal migrations. They also indicated that the period of growth to maturity would take about six to eight months.

Although some temperate species have been studied in detail there are only a few records of their fisheries. Moreover, there is a scarcity of information on fishing gear and fishing seasons. Eifford (1965) sampled *Emerita* by using a cylindrical core sampler with a net on top to prevent the animal from escaping. He also recorded that the species had probably two main predators—shore birds and surf-fish, especially Carbina (*Mentricirrhus undulatus* Girard).

The anomuran sand crabs were formerly used as bait for surf-fishing in Thailand but during the last decade, have become a sea food delicacy, particularly in the Phuket Province. Demands for them in the local market is presently on the increase, and they are being introduced into the Bangkok market.

The present study reports on the biological distribution and ecological observations made on the populations of *E. emeritus* along the Indian Ocean coast of Thailand from May 1971 to May 1973. The study also covers aspects of population dynamics such as size composition, sex ratio, growth rate and observations on the spawning season. Results of observations on species composition, fishing grounds, local fishing techniques, and tidal rhythmic vertical distribution are also presented.

II. MATERIAL AND METHODS

(a) Survey area and stations

*Phuket Province*

Specimens were collected from the airport beach, Mai Kao beach and Suan Maprao beach for a period of two years from May 1971 to May 1973. Each area was sampled twice a month, always on exactly the same dates. About 500 specimens were collected during each trip. A nylon net of 20 mm. mesh size (straight measurement) mounted on a square iron frame of approximately 0.5 m² in area was used for sampling. (Fig. 1). This net was operated along the beach at a depth of 60 cm. of water by holding it horizontally against the slope of the beach and hauling it up just a few centimeters when the surf was receding. The sand crabs washed down by the surf were thus caught in the net before they were able to rebury themselves in the sand. A certain amount of skill and experience was necessary to operate the net successfully. Based on the experience of the first year, the method was slightly modified during the second years as follows: the mesh size of the nylon net was reduced to 10 mm., and the net was
operated at a depth of 30 cm. Specimens were collected during the extreme of high and low tide. Collection was restricted to a total of 25 hauls per trip.

Other sandy beaches in Phuket Province were also occasionally surveyed using the same technique (Map 1).

**Ranong, Phangnga, Krabi, Trang and Satun Provinces**

All observations on the distribution and abundance of sand crabs and specially of *E. emeritus* were carried out during eight monthly oceanographic cruises of the research vessel “Pramong 8” along the entire west coast of Thailand during the period beginning from October, 1972. For the present survey, the whole area was divided into two regions: the northern region comprising the coasts of Ranong and Phangnga Provinces north of Phuket and the southern region consisting of the coastal areas of Krabi, Trang and Satun Provinces (see Map 1). All cruises started from Phuket. The ship operated alternately in the northern and southern regions during the cruises each of which was of 15 to 20 days duration. Throughout the survey, a grid of 40 fixed stations covering the whole area was occupied during each month. All observations were carried out using the same technique as at Phuket. The program was planned in such a way that the ship was anchored for at least one day in each area and all observations on the sandy beaches around that area were carried out during the course of that day.
Map 1—Map of the west coast of Thailand showing the stations in the area of investigation and distribution of *E. emeritus* (L.).
(b) PHYSICAL AND CHEMICAL PARAMETERS

A few physical and chemical parameters, such as temperature of the air, sea water, wet sand and dry sand; salinity and oxygen content of sea water, etc., were measured at the time of sampling the sand crabs. Salinity and oxygen content were analyzed later in the laboratory using the titration methods of Knudsen and Winkler respectively.

The slope of the beach was measured at the three main beaches studied in Phuket Province. Samples of sand collected from various depths along vertical gradients were each analyzed in the laboratory for grain size, composition and distribution.

(c) TREATMENT OF THE SPECIMEN IN THE LABORATORY

Specimens were handled in the Laboratory as follows:

Male and female specimens

First, male specimens were sorted out from the sample on the basis of the presence of genital papillae on the coxopodites of the fifth pair of thoracic legs and also by the absence of pleopod on the abdominal segment. (Snodgrass 1952)

Ovigerous female

A total of one hundred egg-bearing females were studied in detail at an average of five specimens from each sample. The eggs were removed from the pleopod and their dry and wet weight were measured. The number of eggs from each female was also counted in wet condition.

Length and weight measurements:

The length and weight measurements as applied in the present studies are defined as followed:

Carapace Length: The distance along the dorsal midline from the point of rostrum to the median posterior dorsal of the carapace.

Total weight: weight of the whole animal including eggs in ovigerous females.

(d) MORPHOLOGICAL RELATIONSHIPS

The carapace length (X) / total weight (Y) of males and females were calculated to find the correlations from the above measurements.

The regressions were determined by using the equation

\[ Y = a + b_{yx} X \]

where a and b_{yx} are the Y – intercept and slope of the straight line relating Y to X respectively. For correlation of length and weight, the exponential equation

\[ W = cL^n \]

was used, where W is the weight, L is the length and c is the constant.

In the logarithmic form,

\[ \log W = \log c + n \log L \quad \ldots \quad (1) \]

where the constants c and n are determined by the least square method.

If in equation (1):

\[ Y = \log W \]
\[ X = \log L \]
\[ a = \log c \]
\[ b_{yx} = n, \]

then the equation would read

\[ Y = a + b_{yx} X \]

where \( a = \bar{Y} - b_{yx} \bar{X} \)

or \( \bar{Y} = a + b_{yx} \bar{X} \)

\[ b_{yx} = \frac{\Sigma XY - (\Sigma X)(\Sigma Y)}{\Sigma X^2 - (\Sigma X)^2} \]

III. RESULTS

(a) SPECIES COMPOSITION

The investigation on species composition of the anomuran sand crab was carried out along the sandy beach of the west coast of Thailand on the Andaman Sea from May, 1971 to May, 1973. Two genera and two species of the family Hippidae
Fig. 2—*Emerita encelus* (L.)

Fig. 3—*Hippa adactyla* F.
and one genus and one species of the family Albuneidae were found. These three species are as follows:

Family Hippidae

Emerita emeritus (L.) (Fig. 2)
Hippa adactyla F. (Fig. 3)

Family Albuneidae

Albunea symnista (L.) (Fig. 4)

(b) DISTRIBUTION AND FISHING GROUND

General distribution

The anomuran sand crabs were found in some locality of the Phuket and Phangnga Provinces, especially on the exposed sandy beaches along the west coast of the provinces. The east coast of

these two provinces is almost entirely a mangrove area, which is not the habitat of these crabs, therefore they are not present in these areas. In various localities of Ranong, Krabi, Trang and Satun Provinces, these crabs were not found during the two-year investigation.

Species abundance

Emerita emeritus was the most abundant species of anomuran sand crabs in the areas. Two other species, Hippa adactyla and Albunea symnista were found occasionally only, especially A. symnista was very rare. Only twenty-four specimens of Hippa adactyla and three specimen of Albunea symnista were collected during the study.

Fishing areas

The main fishery areas of Emerita emeritus are at three localities, Suan Maprao, Mai Kao and the airport beaches of Phuket Province. The average catch at each of the beaches was 8, 7 and 3 crabs per haul respectively (the duration of operation for one haul is one wave wash zone). They were also found on an average of 1 crab per haul at Chang Sorn beach, 0.3 per haul at Surin beach and 0.2 at Komla Bay. In other localities of Phuket Province, there was no record of the presence of these species (see Map 1).

In Phangnga Province, Emerita emeritus were collected at four localities, namely Tha Noon, Thai Muang, Bang Sak and Ban Kug Kuk beaches, the average catch at each of these beaches were 8, 2, 1 and 0.1 crabs per haul respectively. These localities are not yet considered as fishing grounds by fishermen.

Physical and Chemical Environment

Physical and chemical properties of the sea water, organic matter and the size of sand grain at the fishing grounds were analyzed with the following results:

Temperature of the sea water fluctuated from 28.2-30.9°C.;
Temperature of the dry sand fluctuated from 29.7-42.1°C.;
Fig. 5—Tidal rhythmic vertical distribution of *E. emeritus* (L.).

N = 5933
\[X = 23.00\]

Fig. 6—Size distribution of the female *E. emeritus* (L.) during May 1971 - April 1972.
Temperature of the wet sand fluctuated from 28.8-31.2°C.

Salinity of the sea water varied from 31.47-32.83 ppt.

Oxygen content of the sea water varied from 4.59-6.31 ml/L.

Organic matter on the surface of the sand grain varied from 0.41-1.56 percent of the sand.

The sizes of the sand grain were 2, 1, 0.5, 0.25, 0.125 and 0.063 mm. in diameter; the percentage content of each size was 7.08, 34.30, 8.33, 0.82 and 0.17 respectively.

(c) Tidal Rhythmic Activity and Vertical Distribution

The distribution of E. emeritus in the intertidal zones was found to be in two zones; adult and mixed. The adult zones are always located at the lower part of the beach and most of the specimens are female with carapace length over 12.0 mm. The mixed zones are at the upper part of the beach near the high water level when compared to mean low water sea level and mean high water sea level (Fig. 5). Males and small females with a carapace length of less than 12.0 mm. and some large females with a carapace length of over 12.0 mm. were found in this zone. These two zones move up and down the beach vertically between the wave wash zones. Crabs are never found above the high or below the low water sea level. Considering the population total in relation to the tide, it was greater at low tide than at high tide in the same area.

(d) Size Frequency Distribution

Most of the specimens collected at the lower part or adult zones of the airport, Mai Kao and Suan Maprao beaches whenever it was at high tide or at low tide from May 1971 to April 1972, were females with carapace length between 11.0 mm. to 35.0 mm. The size frequency distribution of the sample showed a consisant mode for the whole period. The predominant number of specimens were 24.0 mm. in carapace length, and the mean carapace length of the samples was 23.0 mm. The largest were 35 mm. (Fig. 6). In comparison, the samples collected at the upper part or mixed

![Figure 7](image.png)

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Fig. 7—Size distribution of male and female during June 1972 - May 1973.
zones of the same localities both at high and low tide from June 1972 to May 1973, showed quite a difference. The size frequency distribution of males and females with class intervals of 1.0 mm. of carapace length of the same collections also showed a considerable difference (Fig. 7). The length of specimens collected fluctuated between 4.0 - 8.0 mm. in males and 4.0 - 30.0 in females. The most predominant size group collected for the whole period was 7.0 - 8.0 mm. for the males (11.5 mm. were the largest specimens) and 15.0 - 16.0 mm. for the females (29.5 mm. were the largest specimens). The mean carapace length of males and females was 7.3 mm. and 14.5 mm. respectively. It was found that in size females were at least two times larger than the males in the population, and female specimens collected at the lower part or adult zones of the beaches were much larger than female specimens collected at the upper part of the beaches. It should also be mentioned that the specimens collected at the lower part of the beaches, either at high tide or at low tide, were all females.

The monthly size frequency distribution of the males and females collected from June 1972-May 1973 at the upper part of beaches in Phuket were found to be of bi-modal from June to November (the Southwest Monsoon period) and became unimodal from December to May in the case of females and uni-modal for the whole year in the case of males (see Fig. 8). The predominant size group of the size-frequency distribution of the monthly samples collected for the whole period was 15.0 - 16.0 mm. for females and 7.0 - 8.0 mm. for males. The maximum abundance for any size group for any month was in June in the case of females and in October in the case of males. The growth rate of females increased from June to November with the carapace length of from 15.0 - 16.0 mm. to 24.0 - 25.0 mm. for the first population and from September to May for the second population.

(c) SEX RATIO

Male to female sex ratio for the total collection of E. emeritus at the Phuket Province and of all the size groups put together were found to be 0.2287:1, or 22.87 percent were males and 77.13 percent were females. The chi-square test value was 6797.77, and the null hypothesis was unconditionally rejected. It means that the sex ratio was significantly different from the hypothesis ratio of 1:1, and there is also a significant difference in every month throughout the year (see Table 1 and Fig. 9). On the basis of monthly averages for all size-groups put together, the highest percentage of males was collected in October (46.16 percent) and of females in June (95.04 percent). If the various size groups are separately considered, in the sex group of 9.0 mm. size, more males than females were found, but in the sex group of over 9.0 mm. size, more females than males were collected and in the group of over 12.0 mm. size, no males were present in the sample.

(f) FECUNDITY

Females in the size range of 20.0 - 29.0 mm. were found to bear eggs. The largest number of ovi-gerous females belonged to the 29.0 mm. carapace length groups. The number of eggs ranged from 500 to 6000 per individual and the relationship between the number of eggs and carapace length was

\[ Y = -3618.22 + 3505.43 \times X \] (Fig. 10)

(g) LENGTH/WEIGHT RELATIONSHIP

The length/weight relationship of E. emeritus was studied from the specimens collected in Phuket Province during the period from June 1972 - May 1973 and were analyzed by the least square method \(Y = a + b_x \times X\) and the exponential equation \(W = cL^d\). The correlations are expressed in diagrammatic form in Fig. 11 for both males and females.

The regression line of male and female is as follows:

\[ \log W = -1.7076 + 3.0560 \log L \ldots \text{male} \]
\[ \log W = -1.8821 + 3.1864 \log L \ldots \text{female} \]
Fig. 8—Monthly size frequency distribution of males and females.
Table 1. Changes in sex ratio of *Emerita emeritus* (L.)

<table>
<thead>
<tr>
<th>Months</th>
<th>No. of males</th>
<th>No. of females</th>
<th>Total male &amp; female</th>
<th>Percent of females</th>
<th>Male/ female</th>
<th>Adjusted chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>162</td>
<td>3104</td>
<td>3266</td>
<td>95.04%</td>
<td>0.0521</td>
<td>2650.1422</td>
</tr>
<tr>
<td>July</td>
<td>468</td>
<td>2099</td>
<td>2567</td>
<td>81.76%</td>
<td>0.2229</td>
<td>1036.2921</td>
</tr>
<tr>
<td>August</td>
<td>285</td>
<td>1129</td>
<td>1414</td>
<td>79.84%</td>
<td>0.2524</td>
<td>503.7743</td>
</tr>
<tr>
<td>September</td>
<td>205</td>
<td>680</td>
<td>885</td>
<td>76.83%</td>
<td>0.3014</td>
<td>254.9445</td>
</tr>
<tr>
<td>October</td>
<td>738</td>
<td>861</td>
<td>1599</td>
<td>53.84%</td>
<td>0.8571</td>
<td>9.4621</td>
</tr>
<tr>
<td>November</td>
<td>182</td>
<td>802</td>
<td>984</td>
<td>81.50%</td>
<td>0.2269</td>
<td>390.6513</td>
</tr>
<tr>
<td>December</td>
<td>318</td>
<td>1344</td>
<td>1662</td>
<td>80.86%</td>
<td>0.2366</td>
<td>635.8513</td>
</tr>
<tr>
<td>January</td>
<td>117</td>
<td>1237</td>
<td>1354</td>
<td>91.35%</td>
<td>0.0945</td>
<td>926.4408</td>
</tr>
<tr>
<td>February</td>
<td>76</td>
<td>832</td>
<td>908</td>
<td>91.62%</td>
<td>0.0913</td>
<td>629.4460</td>
</tr>
<tr>
<td>March</td>
<td>76</td>
<td>589</td>
<td>665</td>
<td>88.57%</td>
<td>0.1290</td>
<td>395.7443</td>
</tr>
<tr>
<td>April</td>
<td>200</td>
<td>751</td>
<td>951</td>
<td>78.96%</td>
<td>0.2663</td>
<td>319.2449</td>
</tr>
<tr>
<td>May</td>
<td>385</td>
<td>614</td>
<td>999</td>
<td>61.46%</td>
<td>0.6270</td>
<td>52.4944</td>
</tr>
<tr>
<td>Total</td>
<td>3212</td>
<td>14042</td>
<td>17254</td>
<td>81.38%</td>
<td>0.2287</td>
<td>6797.77</td>
</tr>
</tbody>
</table>

Fig. 9—Monthly variation in sex ratio of *E. emeritus* (L.)
IV. DISCUSSION AND CONCLUSIONS

The result obtained on species composition of the anomuran sand crab collected along the west coast of Thailand during the period from May 1971 to May 1973 comprised of Emerita emeritus and Hippa adactyla of the family Hippidae and Albunea symnista of the family Albuneidae.

Schmitt (1935) established E. asiatica (H. Milne Edwards, 1837) as a synonym of E. emeritus Alikunhi (1944) and Menon (1934) also mentioned that E. emeritus was known as E. asiatica or Hippa asiatica. In Thailand E. emeritus was also previously recorded as E. asiatica (Tiensongrumsnee, 1972).

H. adactyla was found to be a new record for Thailand, and Albunea symnista was also collected for the first time in this area.

In Phuket and Phangnga Provinces anomuran sand crabs were present only in a special environment, especially on very exposed sandy beaches facing the open sea with a channel for fresh water runoff. There are three main fishing areas on the west coast of Phuket's sandy beaches, namely Suan Maprao, Mai Kao and the airport beaches. The crabs were caught from each beach on an average of 8, 7 and 3 individuals per haul respectively. The maximum catch per haul was 73 individuals at Suan Maprao beach at low tide. They were also collected at Chang Sorn beach, Surin beach and Koma Bay areas with an average catch not exceeding 1 animal per haul. Therefore, most of the crab supply for the demand of the market was collected at the former three localities.

On the exposed sandy beaches at Tha Noon, Thai Muang, Bang Sak and Ban Kug Kuk of the Phangnga Province are only four localities where the animal was caught with an average of 8, 2, 1 and 0.1 animal per haul respectively. Of these, two, Tha Noon and Thai Muang, could develop to be fishing grounds in the future.

At other localities in Ranong, Krabi, Trang, and Satun Provinces and on the east coast of Phuket and Phangnga Provinces, the anomuran
sand crabs were not present because most of these areas are muddy. The sandy beach of these areas might also have other limiting factors such as organic and inorganic matter, wave action, size of the sand grain—factors differ from those of the present fishing grounds.

Of the three existing species, *E. emeritus* is the most common and abundant in the area. The other two species are very limited. They have occasionally been recorded. Donax clams and some fishes are the other animals which are always collected with the anomuran sand crabs.

In 1966, anomalun sand crabs were not a popular source of sea food in Phuket. They were very abundant and could be caught by hand in the wave wash zone on the sandy beach. Now, they have become a very popular source of sea food, with a high demand in the local market. Therefore, fishing techniques and fishing gear have been developed. A nylon net with a rectangular frame is now the most effective fishing gear; it is operated along the sandy beach at low tide in the wave wash zone. The net is held down under the water near a group of emerged crab antennae from the surface of the sand which indicate the center of the location of abundance. The fisherman holds the frame of the net and steps back to the beach. The crabs are then caught as they move back into the sea. Some hauls of more than 50 crabs were made. During the last two years, there have been competitions for catching the crabs, owing to high demand in the market; therefore, some chemicals were also applied for fishing. As a result, all size groups in the population were killed.

*E. emeritus* sand crabs moved on a vertical migration into two zones of the intertidal zone. Adult female crabs with carapace length of over 12.0 mm were found at the lower part of the beach where there is a substratum of coarse sand, but no males were present in the samples collected at the lower part of the beach. The mixed zone presents both males and females with a carapace length of less than 12.0 mm, and also some females with a carapace length of over 12.0 mm. This zone was located at the upper part of the beach where the substratum is of fine sand. The animals never occurred beyond the low water level. These findings would support Eifford’s report in 1967. In this case, the zoning might depend on animal oxygen consumption demand, for it was found that there is more dissolved oxygen in the inter-spaces of coarse sand than in the inter-spaces of fine sand.

The distribution of males was uni-modal for the whole year and they were present at the upper part of the beach. During the monsoon period (June to November), the predominant size group of males was 6.0-9.0 mm in carapace length, which is the mature size for males. Very few males in the size groups from 9.0 - 11.0 mm were found. From January to April, the male were usually represented by the lower class length of between 5.0 - 6.0 mm in carapace length. This shows that these males have just recently arrived on the beach.

At the upper part of the beach, the distribution of females was bi-modal during the monsoon months and became uni-modal from December to May. This indicated the presence of a new population recently added to the population during period from June to November and that the original population moved to the lower part of the beach after November. The specimens collected at the lower part of the beach whether it was high tide or low tide from May 1971 to April 1972 showed that specimens of the carapace length from 11.0 mm up to 35.0 mm are mostly females. The mean of carapace length of female specimens at this part of the beach was 23.0 mm, which is a marketable size, occurring in maximum abundance in June.

The length of the specimens collected at the upper part of the beach from June 1972 to May 1973 fluctuated between 4.0 - 8.0 mm. in the case of males and 4.0 - 30.0 mm. in the case of females. The predominant size groups were 7.0 - 8.0 mm for males and 15.0 - 16.0 mm for females. The mean of carapace length of males and females was 7.3 mm. and 14.5 mm., respectively. The maximum abundance for any size group occurred in June in the case of females and in April in the case
of males. The growth rate of females increased from June to November with the carapace length of 15.0 - 16.0 mm. to 24.0 - 25.0 mm.

This clearly showed that the mature males with carapace length of 6.0 - 9.0 mm. and females with carapace length of 15.0 - 16.0 mm. matched and spawned at the upper part of the beach during the monsoon. In this period, both male and females are mature and are in the composition of the population. The old males disappeared from the beach after October while the females reached their maximum size after November and moved to the lower part of the beach to find more dissolved oxygen, food, etc.

The males and females were collected in a ratio of 1:5 for all size groups put together throughout the year. It meant that the number of males in the population was smaller than the number of females throughout the year. The test of difference in number of males and females by chi-square method showed that the high values of adjusted chi-square were obtained for the whole year. It is, thus, proved that the sex ratio of male to female significantly departed from the hypothetical ratio of 1:1. The results of this study also found that more males than females were collected in the sex group with carapace length of 9.0 mm., but in the sex group of over 9.0 mm. in size, more females than males were collected, and in the group of over 12 mm. in size no males were collected. On the basis of monthly average for all size-groups put together throughout the year, the maximum abundance of males was found to be in October (46.16 percent) and that of females in June (95.04 percent).

Ovigerous females with carapace length of 20.0 - 29.0 mm. bearing eggs varies from 500 to 6000 eggs which can be calculated from the equation:

\[ Y = -5618.22 + 3505.43 \times X \]

when \( X \) = carapace length in cm. of ovigerous female

\( Y \) = number of eggs

or determined from the graph in Fig. 10

The results obtained on the length/weight relationship of the *E. emeritus*, both male and female correspond.

V. SUMMARY

1. Studies on distribution, tidal rhythmic vertical distribution, species composition, fishing ground, fishing techniques and population dynamics of anomuran sand crabs along the west coast of Thailand were carried out during May 1971 to May 1973.

2. Three species of the crabs were found and one of these, *H. adactyla* is a new record for Thailand. Other two species, *E. emeritus* and *A. synnista* which were previously known in Thailand are discussed.

3. The most abundant species is *E. emeritus* which was found at three localities, i.e. Suan Maprao, Mai Kao and the airport beaches of the Phuket Province and at two areas of the Phangnga Province, namely Tha Noon and Thai Muang beaches. On other sandy beaches of Ranong, Krabi, Trang and Satun Provinces, the animals were not found.

4. The most effective fishing time are operated at the low tide during June to November.

5. There exist two zones, adult and mixed zones, of the tidal rhythmic vertical distribution of *E. emeritus* in the intertidal zone. The adult zones are always located at the lower part of the beach and mixed zone are located at the upper part of the beach.

6. The predominant size group collected at the upper part of the beaches was 7.0 - 8.0 mm. of carapace length in the case of male and 15.0 - 16.0 mm. in the case of female. The mean of carapace length of males and females were 7.3 mm. and 14.5 mm. respectively. The predominant size group collected at the lower part of the beaches was 24.0 mm. in carapace length and the mean of carapace length of the samples was 23.0 mm. which is the marketable size. It can also be mentioned that females are larger than males by at least two time and that females collected at the
lower part of the beaches were much larger than females collected at the upper part of the beaches.

7. The maximum abundance for any size group occurred in June in the case of females and in October in the case of males.

8. Males and females matched and spawned at the upper part of the beaches during the monsoon period.

9. Sex ratio of *E. emeritus* was found to be 22.87 percent male and 77.13 percent females. On the basis of monthly average for all size group put together, the highest percentage of males was collected in October, (46.16 percent) and of female in June (95.04 percent). If the various size groups are separately considered, in the sex group of 9.0 mm. size, more males were found than female, but in the sex group of over 9.0 mm. size, more females were found than males and that of over 12.0 mm. size, no males were collected.

10. Ovigerous females are in the size range of 20.0 - 29.0 mm. in carapace length, the number of eggs varied from 500-6000 per individual depending on the size of ovigerous female. The relationship between the number of eggs and the size of female bearing egg are $Y = -5618.22 + 3505.42 \times X$.

11. The length/weight relationship for males and females are correlated and are expressed separately in diagrammatic form.

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