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Studies on the fisheries biology of the giant tiger prawn, *Penaeus monodon* in the Philippines

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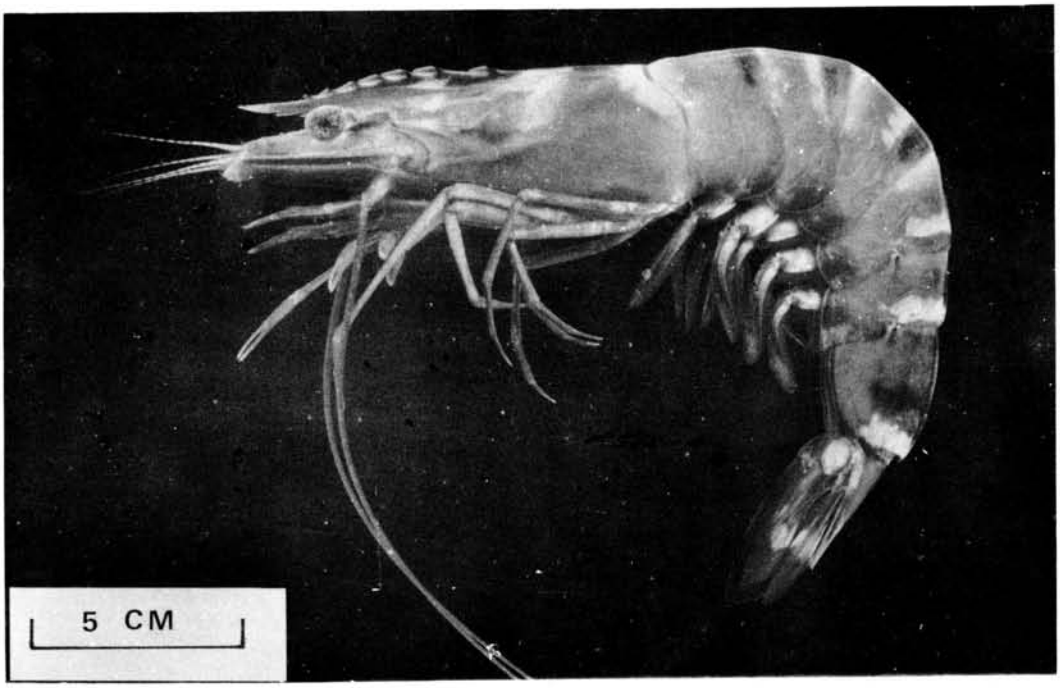

Adult female of the giant tiger prawn, *Penaeus monodon* **FABRICIUS.**

STUDIES ON THE FISHERIES BIOLOGY OF THE GIANT TIGER PRAWN, *PENAEUS MONODON*, IN THE PHILIPPINES

Hiroshi Motoh

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I. INTRODUCTION

I-1 Purpose

The giant tiger prawn, *Penaeus monodon* FABRICIUS is one of the largest penaeid prawns in the world reaching 260 mm in body length or 250 g in weight, and is of commercial importance not only in the Philippines but also in other Southeast Asian countries.

In the Philippines, enthusiasm for the natural and artificial propagation of both fry and adult giant tiger prawn is growing rapidly among government and private aquaculturists, due to strong demand and higher prices, both in the national and international markets. There is little evidence of large catches of the giant tiger prawn being taken at one time in offshore waters, probably due to the biological characteristics of the species. On the other hand, expansion of pond cultivation has been constrained by a continuous shortage of wild fry, while with hatchery rearing of fry, heavy mortality, sometimes as high as 75 %, is still a serious problem.

At present, the ecology and life history of the giant tiger prawn with regard to seasonal abundance of fry and adults, spawning season/area, larval development, and migration/transportation are not yet well documented.

Thus, the main objectives of the study are as follows: A) (i) To understand the principal characteristics of the species with regard to life history and environmental factors, (ii) to review the present status of fisheries for *P. monodon* in the Philippines. B) Based on the knowledge of recruitment of wild fry, to make recommendations for the effective utilization of natural resources of both fry and adults to achieve maximum sustainable yields by regulation of fishing activities to avoid overfishing, and by conservation of habitats.

1-2 Review of literature

In 1798, Fabricius described this prawn as a new species in his monograph and proposed the name, *Penaeus monodon.*

In the Philippines, Blanco and Arriola (1937), Villaluz and Arriola (1938) and Cases-Borja and Belnas (1976) made taxonomic studies of *P. monodon.*

Regarding larval development of *P. monodon,* Villaluz *et al.* (1969), Liao *et al.* (1969), Kungvankij (1976), and Motoh (1979) described six naupliar, three protozoea (or zoea) and three mysis substages. Recently studies on the gonadal development and maturation of the female giant tiger prawn have become important due to the demand for spawners necessary in the various research and commercial hatcheries.

Studies on the food and feeding habits of *P. monodon* have been accomplished by Hall (1962), Thomas (1972) and Marte (1980), indicating that *P. monodon* is an omnivore. Alikunhi *et al.* (1975) and Wear and Santiago, Jr. (1976) successfully induced ovarian maturation and spawning of *P. monodon* in captivity using the technique of eyestalk ablation originally developed by Alikunhi *et al.* (1975) for *P. indicus.* Primavera (1979) observed the courtship and mating of *P. monodon* in captivity.

Regarding the production of *P. monodon,* studies include those of Liao and Chao (1977) reviewing the problems of the culture of *P. monodon* in Taiwan, Yap *et al.* (1979) and Primavera and Apud (1977) preparing manuals on prawn farming in the Philippines.

Moller and Jones (1975) studied locomotory rhythms and burrowing habits of *P. monodon,* and Hughes (1966) investigated the nursery area and habitat preference of the juveniles in South Africa. Mohamed (1970) provided a synopsis of biological data on the giant tiger prawn for FAO.

II. FISHERIES OF GIANT TIGER PRAWN

In the Philippines, *P. monodon* is locally called "sugpo" (Tagalog), "lukon" (Ilongo), or "pansat" (Cebuano), and is the most commercially important species among edible crustaceans and has attained a peak price of ₱95*/kg in Manila or ₱75 in other cities for larger sizes (Motoh and Kuronuma, 1980).

For more than 50 years, *P. monodon* has been traditionally cultured in brackishwater fishponds in the Philippines together with the milkfish, *Chanos chanos.*

According to statistics (SEAFDEC, 1978), the annual catch of penaeid prawns in the Philippines is about 33,660 metric tons with a value of about 23 million US dollars in 1976. Prawns are mainly taken by some 900 offshore trawlers and numerous fish corrals. Among these, the annual yield of *P. monodon* is estimated to be about 2,000 metric tons (Nukiyama, personal communication), of which about half is obtained from off and onshore waters, and other half from milkfish ponds as a by product from some 176,000 ha. About 2,400 metric tons of penaeid prawns both from the wild and from pond, mostly *P. monodon* and *P. semisulcatus,* are exported to Japan which is the biggest importer of the species in the world. There is a trend towards the use of fishponds to meet the demand for this palatable animal. Many fishpond owners are eager to convert their milkfish ponds to prawn ponds, as the latter offers higher profitability compared to milkfish.

Although the number of individuals of *P. monodon* caught is not predominant anywhere compared with other penaeid species, the catches of *P. monodon* are commercially very important due to the particular demand for this species in the Philippines.

In general, penaeid prawns can be classified into three groups according to their retail prices: (1) *P. monodon* worth about ₱80/kg, (2) other *Penaeus* spp. worth about ₱35/kg and (3) *Metapenaeus* spp. worth about ₱25/kg.

At present, fisheries activity for *P. monodon* as well as other useful penaeids may be traditionally classified into four categories: (1) offshore fishery by big trawlers for adults, (2) inshore and onshore fisheries by fish corrals and small trawlers for adults, (3) pond cultivation in brackishwaters, and (4) fry collection mostly in brackishwaters.

One of the characteristics of the *P. monodon* fishery in the Philippines is fry collection along the shore waters, river mouths and mangrove areas for supplying the seed to the prawn ponds. This business is commercially important for people inhabiting rural areas as a sort of extra income.

Prawn cultivation in brackishwater ponds has been traditionally carried out as a secondary crop in milkfish culture. The potential of this promising industry in the Philippines might be attributed to the following reasons:

1) *P. monodon* from fry to adult in general has great tolerance to environmental fluctuations, thus it is relatively easy for pond caretakers to let them grow in the ponds.
2) The species has rapid growth and attains a large size.
3) The flavor is good and they are in demand both nationally and internationally, which results in high prices.
4) In general, the fry are easily identified and collected by rural people, and are found locally and seasonally, furthermore, fry are available the whole year round.
5) There are plenty of low cost, unpolluted brackishwater ponds which provide areas for extensive prawn culture.

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*US $1 = ₱7.5.

6) Prawn cultivation is possible all year round due to relatively stable water temperatures associated with their latitudes, although seasonal patterns of rainfall in some areas may be a constraint.

Recently the technology for the artificial production of postlarval *P. monodon* (seed or fry) has been established by the Aquaculture Department of the SEAFDEC as follows:

Before the larvae have metamorphosed into protozoea, the cultured diatom (*Chaetoceros calcitrans*) is introduced into the rearing tank.

Diatom density varies from 5,000 to 20,000 cells/ml as feed during protozoea and mysis stages, while some *Artemia* nauplii are sometimes added during 3rd mysis and 1st megalopa (postlarval) stage when available. The rearing water is changed from time to time to avoid pollution due to feces and uneaten food.

The survival during protozoea is generally high at more than 65 %, but after it metamorphoses into mysis, the survival is quite low particularly between the 3rd mysis and the 1st megalopa as shown in Fig. 1. The cumulative survival rate is 32.9 % on the average from nauplius to the 1st megalopa.

When larvae are infected with the disease caused by *Lagenidium* sp. (fungus), larval survival drops abruptly regardless of the stages, resulting in total mortality.

The basic procedure of larval rearing for the production of postlarvae is principally the same as that for *P. japonicus* developed in Japan. However, relatively heavy mortality occurs during the protozoea stages in *P. japonicus,* while during the mysis stage in *P. monodon.* Furthermore, during the adolescent stage *P. japonicus* are sometimes attacked by *Fusarium* sp. (Mochizuki, personal communication) resulting in total mortality, while in *P. monodon* there has been no report of this disease in the Philippines.

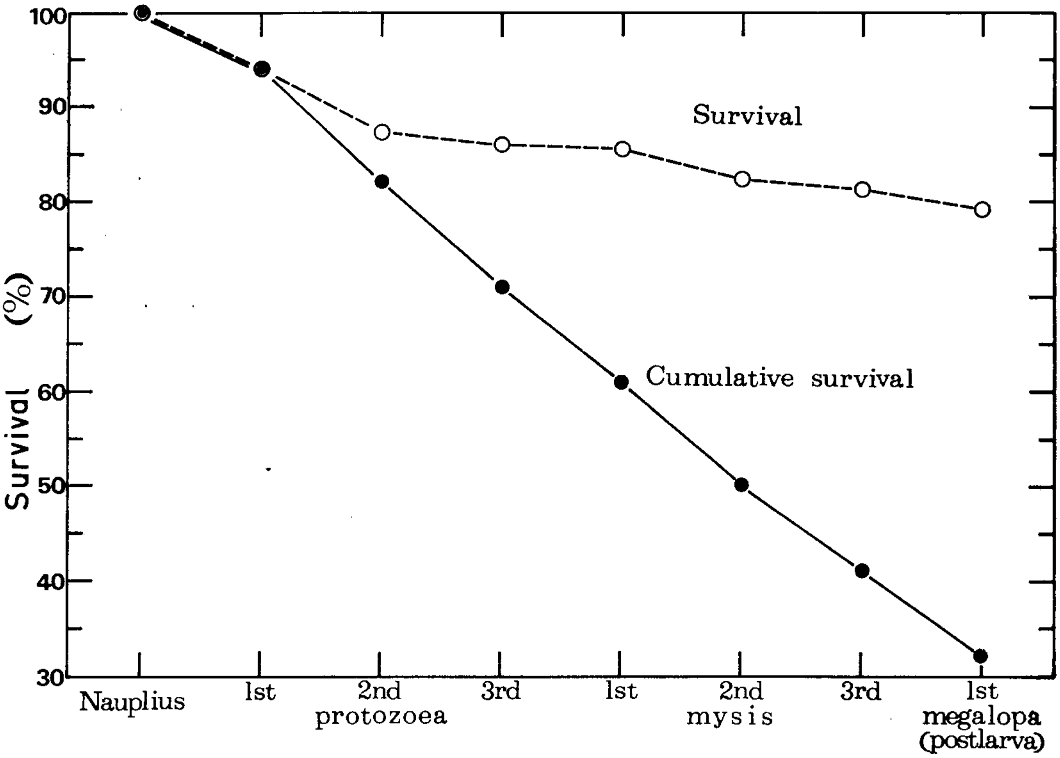

Fig. 1. Survival curves of reared larval *P. monodon* based on 77 experiments.

Discussion

In Japan, the fry of *P. japonicus* are being produced in large scale concrete hatcheries: 200 T or 500 T up to 2,000 T. Upon reaching the P_{20} size the fry are usually harvested. On the other hand, this kind of large scale hatchery is neither economical nor practical in the Philippines for the following reasons:

i) Difficulty in collecting many spawners at a time due to lack of cooperation from fishermen, and to bad transportation conditions. In addition, *P. monodon* usually occurs sporadically.
ii) Labour costs are in general, lower in this country than in Japan. In fact, large scale hatcheries were constructed to reduce labour cost which accounts for some 40% of all expenses in Japan.
iii) Such large scale hatcheries require capital both in construction and operation. This generally does not fit the Philippine conditions particularly in rural areas.
iv) The small scale hatchery has generally lesser risk in terms of the survival of the larvae than in large hatcheries. At present, techniques of fry production are still in development, unlike those for *P. japonicus* in Japan, and for both *P. japonicus* and *P. monodon* in Taiwan.

It is interesting to note that heavy mortality usually occurs during the mysis stage in *P. monodon,* but during the protozoea stage in *P. japonicus.* This might be due to the differences between the species, as well as climatic conditions.

In general, the fry production of *P. monodon* can be practiced more economically than that of *P. japonicus,* for the following reasons:

i) *P. monodon* requires a lower protein level, thus it is not necessary to supply *Artemia* which is a most expensive feed.
ii) It is not always necessary to supply chemical fertilizers such as Sodium silicate (Na_2SiO_3) and Potassium nitrate (KNO_3) due probably to the nutrient rich seawater. In addition, high temperature and sunlight are present which are necessary for promoting diatom blooms.
iii) The *P. monodon* fry can be harvested earlier ($P_{5\text{-}10}$) than *P. japonicus* (P_{20}), the faster growth of *P. monodon* resulting in more economical production (shorter period of rearing and higher survival). Furthermore, *P. monodon* fry are stocked in nursery ponds before transferring to grow out pond. Thus more delicate fry are acceptable, unlike *P. japonicus* which are sometimes released directly to the open sea for the purpose of "restocking".
iv) Labour costs are lower in this country as mentioned earlier and the year round production is practical owing to the availability of spawners any season and the absence of a cold season.

III. MATERIALS AND METHODS

The field survey during the present study was conducted throughout almost the entire Philippines from Aparri (Babuyan Channel, Luzon) in the north and to Bislig and Zamboanga (Mindanao) in the south. Collections of fry and adults were made both by commercial and research methods and hearsay evidence from fishermen on

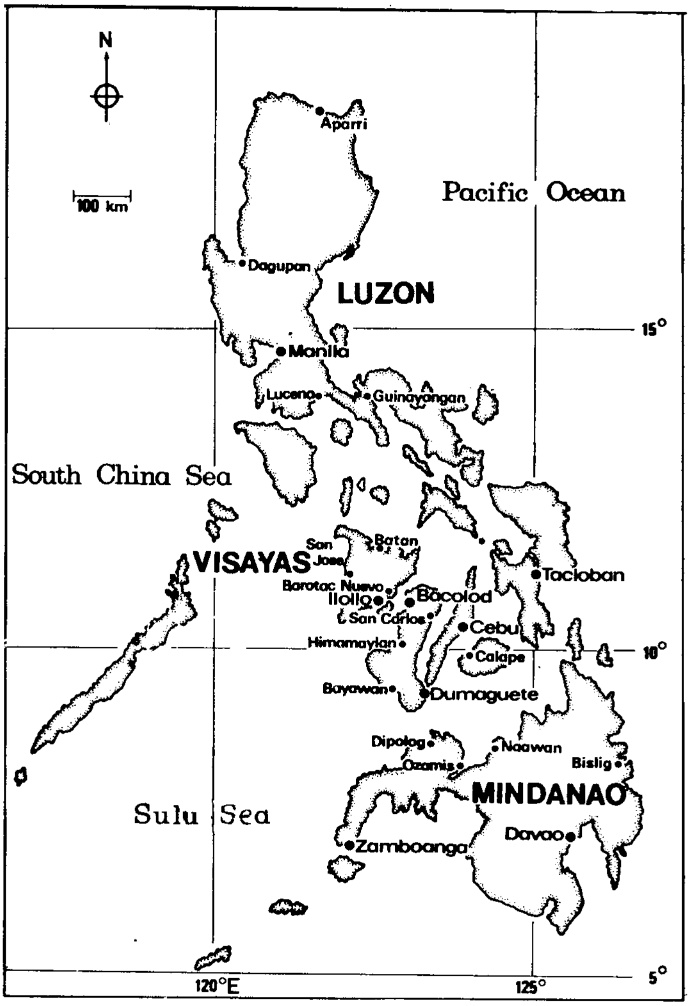

Fig. 2. Map showing the Philippines and the places visited.

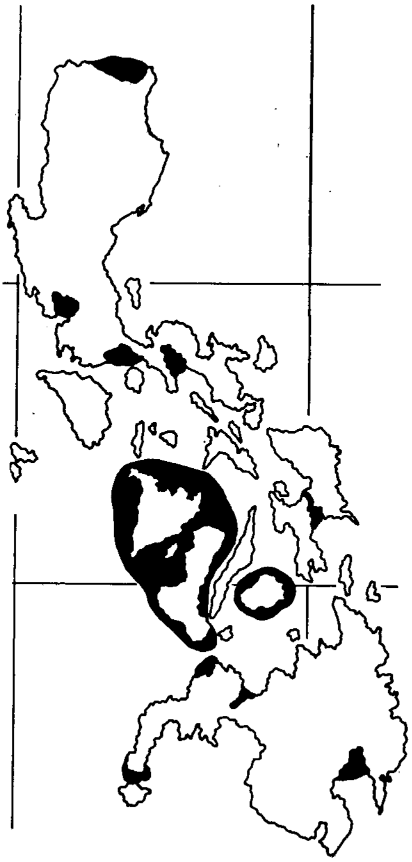

Fig. 3. Map showing the survey areas for the occurrences of fry and adult *P. monodon.*

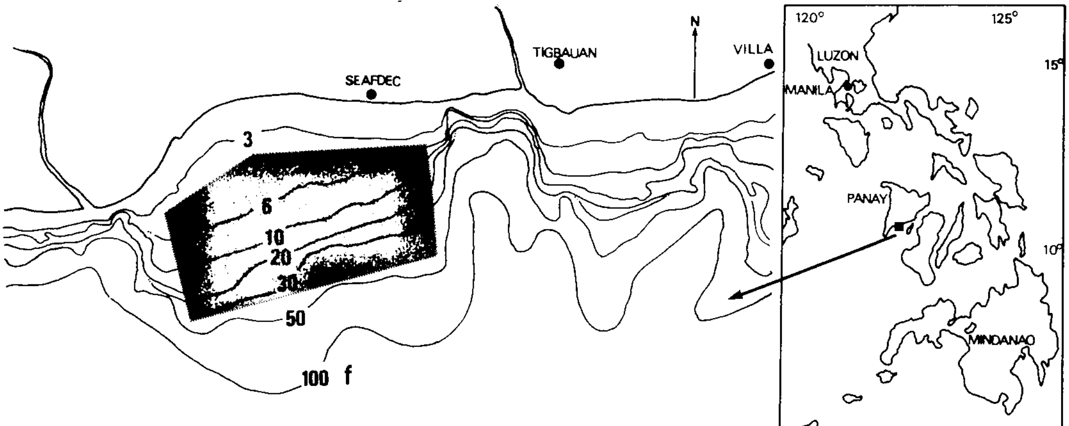

Fig. 4. Map showing the experimental trawling area off Tigbauan.

the seasonal occurrences of fry and adults (particularly the spawners) of *P. monodon* (Figs. 2 and 3). More regular, periodical and successive surveys were mainly carried out around Panay Island located in the central Philippines, viz. at Batan Bay, at th shore waters of Villa and Tigbauan, Iloilo (Fig. 4).

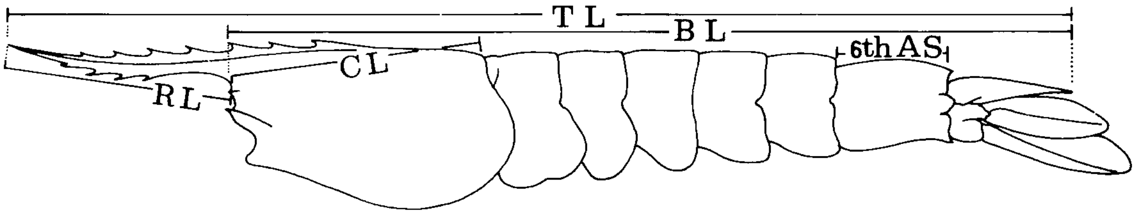

Fig. 5. Method of measurement of *P. monodon.*

Larval collections were made using a 0.44 mm mesh plankton net with a mouth of 75 cm diameter. Tows were made horizontally for a period of 10 minutes at a speed of 1.5 knots. Protozoea and mysis of *P. monodon* were not separated from those of other *Penaeus* spp. due to their morphological similarities, although the megalopa and advanced stages were identified.

Samplings of postlarval *P. monodon* as well as other *Penaeus* spp. were conducted regularly along shore waters with a triangular push net locally called "sagap" for analyses of the size composition and the seasonal occurrence, and less frequently with another type of push net locally called "fry bulldozer" for the size composition. The "sagap" with a mesh size of 0.9 mm and with a mouth of 3 m wide was operated in the morning (0630-1100 hours) by one person wading along the shore waters of Villa and Tigbauan, in water varying from 90 to 120 cm deep over a sand or mud-sand bottom. One sampling with the "sagap" usually consisted of walking the net back and forth along a 100 m (about 7 minutes) stretch of the shore 10 times making a total swept distance of 2,000 m, equivalent approximately to 6,000 m^2 of swept area; while with the fry bulldozer, sampling practice varied.

For a 96-hour survey, frequency of the sampling was every 2 hours. Samples were fixed in a solution of about 10 % formalin diluted with seawater. Postlarvae were later sorted, identified, measured and counted in the laboratory. The postlarval identification was made with the key provided (p. 89). It was not possible, however, to distinguish *P. merguiensis* from *P. indicus,* or *P. japonicus* from *P. latisulcatus* and *P. longistylus* due to the similarity of their morphological characteristics.

The laboratory studies were conducted at the wet laboratory, the biology laboratory and the hatchery of the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC) at Tigbauan, Iloilo, Philippines.

Temperatures were measured with a mercury thermometer and salinity with an AO Goldberg refractometer or a salinometer-bridge.

Measurements were made to the nearest 0.01 mm with the aid of an ocular micrometer under a binocular microscope for larvae and juveniles, or with sliding calipers to an accuracy of 0.1 mm for larger specimens.

The definition of each measurement shown in Fig. 5 are as follows:

Rostrum length (RL): the distance between the tip of the rostrum and the post-orbital margin of the carapace.

Carapace length (CL): the distance between the post-orbital margin and the medial posterior border of the carapace.

Body length (BL): the distance between the post-orbital margin and the tip of the telson with the abdomen extended in a straight line.

Total length (TL): the distance between the tip of the rostrum and the tip of the telson with the abdomen extended in a straight line.

Sixth Abdominal segment: the dorsal distance between the anterior margin of the 6th abdominal segment and its posterior margin excluding the postero-dorsal spine.

Body weight (BW) was determined to an accuracy of 0.001 g using an analytical balance for megalopa and juveniles, or to an accuracy of 0.1 g using a semi-automatic table balance for larger specimens.

The study covers 5 years from May 1975 to June 1980. The methods will be explained in more detail in each section or part, as necessary.

IV. IDENTITY

IV-1. Taxonomy

In 1798, the original description of *Penaeus monodon* was published by John Christ Fabricius. The name *P. monodon* has been used by several authors for the species presently indicated by the names *P. semisulcatus, P. carinatus, P. tahitensis, P. caeruleus, P. bubulus,* and *P. monodon* var. *manillensis,* of which the first name is valid for another allied species, the other 4 are synonyms, and the last proven to be based on an abnormal specimen of *P. semisulcatus.*

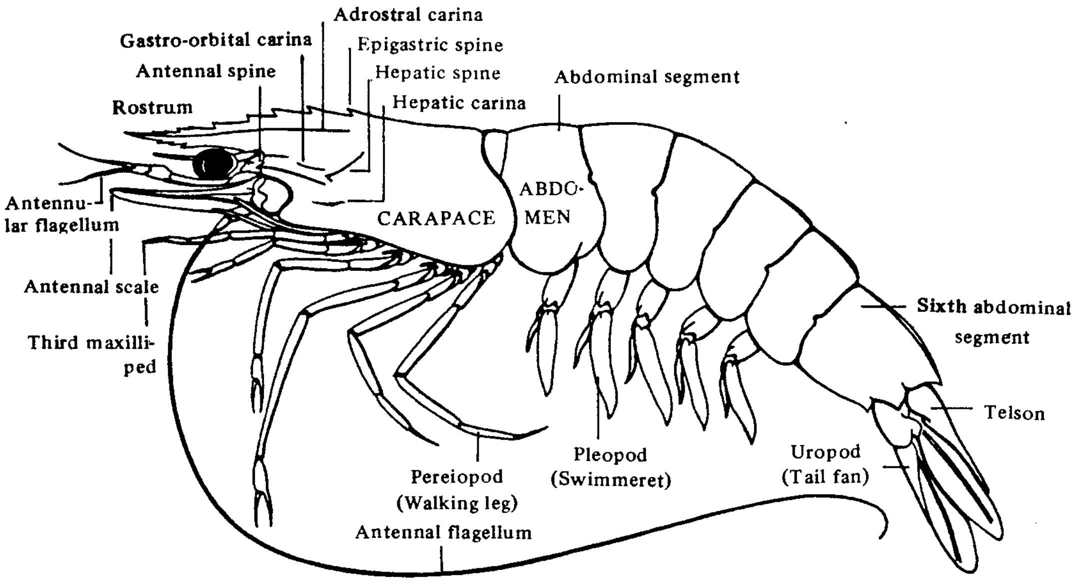

Fig. 6. Lateral view of adult giant tiger prawn, *P. monodon* showing technical terms.

In recent years the nomenclature of *P. monodon* has become standardized and it is generally acceptable for the present species. Kubo (1949) classified species of adult *Penaeus* into 3 sub-divisions: *P. japonicus*-group, *P. monodon*-group, and *P. orientalis*-group, based on the conditions of the adrostral carina or groove and the presence or absence of the hepatic and gastro-frontal carinae. Pérez Farfante (1969) proposed 4 subgenera, viz. *Litopenaeus, Fenneropenaeus, Penaeus* s.s., and *Melicertus* of which the first two are always on the move in the turbid water, while the *Melicertus* prefers well defined habitat, and the *Penaeus* s.s. belongs to an intermediate group from the morphological and ecological points of view. *P. monodon* belongs to the intermediate group, *Penaeus* s.s. (Pérez Farfante, 1969; Kurata, 1978).

IV-2. Morphology

The rostrum, extending beyond the tip of the antennular peduncle, has six to eight (mostly seven) dorsal and two to four (mostly three) ventral teeth, and is sigmoidal in shape. The adrostral carina reaches almost to the epigastric spine. The carina reaches to the posterior edge of the carapace. The gastro-orbital carina occupies the posterior one-third to one-half distance between the post-orbital margin of the carapace and the hepatic spine. The hepatic carina is predominant and the anterior half is horizontal. The antennular flagellum is sub-equal to, or slightly longer than the peduncle. The 5th pereiopod has no exopod. The abdomen is carinated dorsally from the anterior one-third of the 4th to 6th somites. The 4th and 5th somites each has a small lateral cicatrice, and 6th, three lateral cicatrices. The telson is unarmed.

The color of this species in life is as follows: Carapace and abdomen are transversely banded with red and white. The antennae are grayish brown. Pereiopods and pleopods are brown and fringing setae red. Upon entering shallow brackishwaters or when kept in ponds, the color changes to dark brown, and often to blackish.

V. DISTRIBUTION

V-1. World

The giant tiger prawn is widely distributed throughout the greater part of the Indo-West Pacific region: Southern Japan (Kishinouye, 1900; Nakazawa, 1915; Kubo, 1949); Taiwan (Liao and Chen, 1972; Lee and Yu, 1977); Korea (Yoshida, 1941); Hongkong (Wear and Stirling, 1974); Philippines (Villaluz and Arriola, 1930; Blanco and Arriola, 1937; Estampador, 1959); Malaysia (Hall, 1962; Chua, 1978); Singapore (de Man, 1911; Hall, 1962); Thailand (Kungvankij *et al.,* 1973); Sri Lanka (de Bruin, 1965); India (Shaikhmahmud and Tembe, 1960; Mohamed, 1976); Pakistan (Alcock, 1906); Tanzania (Anonymous, 1973b); South Africa (Hall, 1966); Joubert, 1965); and Australia (Dall, 1957; Racek, 1959).

In general, *P. monodon* is distributed from 30°E to 155°E in longitude and from 35°N to 35°S in latitude (Fig. 7).

However, the fishing grounds are mostly located in tropical countries, particularly in Malaysia, Indonesia and the Philippines.

V-2. Philippines

The Philippines, consisting of three main islands or island groups: Luzon, Visayas and Mindanao, and some 7,100 islets, is located in the tropical zone, ranging from 5 to 19°N and from 117 to 127°E (Fig. 2).

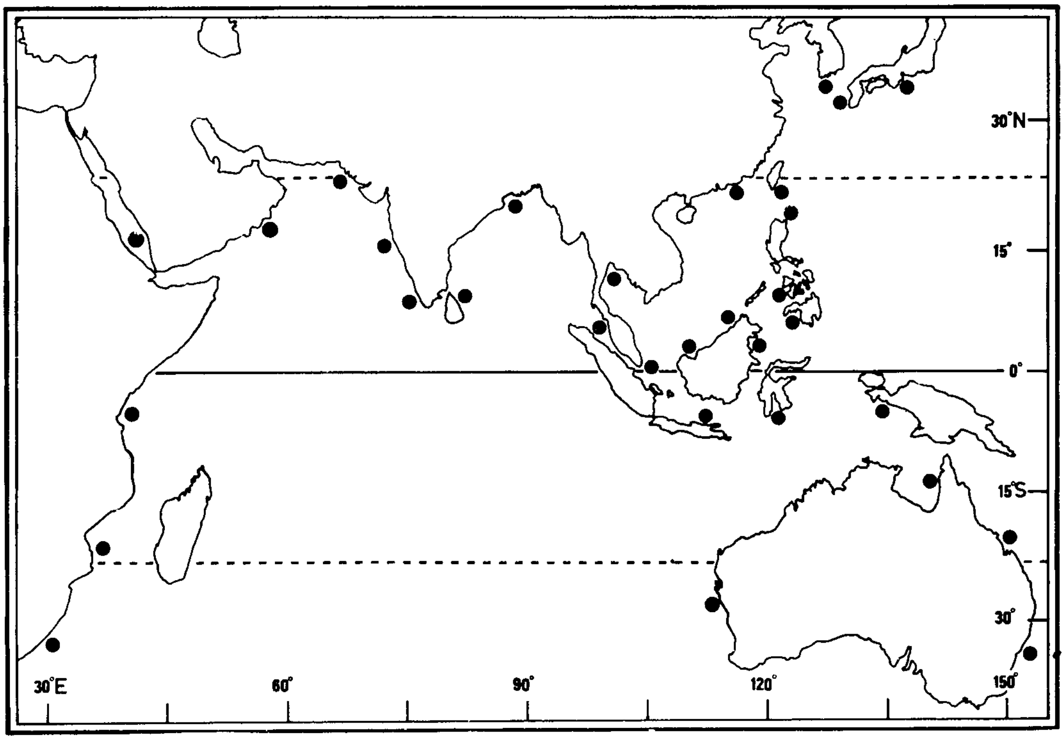

Fig. 7. Distribution of *P. monodon* in the world.

The "sugpo" (*P. monodon*) is distributed throughout the Philippines from Aparri in the north to Zamboanga in the south, although the main prawning grounds are in Luzon and the Visayas.

V-3 Vertical distribution

Juvenile and adolescent *P. monodon* are recorded from surface waters in estuaries (Hughes, 1966), while most of the adults inhabit waters down to 162 m (90 fathoms) (Racek, 1951).

In the Philippines, during the present study, the vertical distribution was found to be from surface in brackishwater rivers down to about 70 m offshore, where the range of water temperature and salinity was between 22 and 34 °C, and 4 and 35 °/oo, respectively.

In prawn ponds, the range of the physico-chemical conditions is generally greater than those under natural conditions.

VI. REPRODUCTION

The prawns used for the present study were obtained from fish corrals and from commercial trawlers. Gonads were fixed in either Bouin's fluid or 10 % neutralized formalin solution in the field, and were dehydrated with alcohol, embedded in paraffin and stained with Heidenhain's hematoxylin and eosin in the laboratory. Paraffin sections were cut at 6 to 8 microns thick.

Male prawns were not used to indicate spawning activity because a satisfactory method for determining the stage of sexual maturity has not yet been devised. Also, the testes which were entirely within the cephalothorax were difficult to observe.

VI-1. Genital organ

A. Male organ

The male genital system consists of internal organ, viz. paired testes, paired vas deferens and paired terminal ampoules, and external organs, viz. a petasma and a pair of appendix masculina.

The testis, an unpigmented and translucent organ, is composed of an anterior and five lateral lobes located in the cardiac region dorsally to hepatopancreas under the carapace. The lobes are connected to each other at their inner ends and lead to the next organ, the vas deferens. The vas deferens arises from the posterior margins of the main axis of the testes and opens to the exterior through genital pores located medially on the coxopod of the 5th pereiopod (Fig. 8). Each vas deferens consists of four distinct portions: a short, narrow, proximal portion (proximal vas deferens), a thickened large medial portion having a double fixture (medial vas deferens); a relatively long narrow tube (distal vas deferens); and a muscular portion (terminal ampoule).

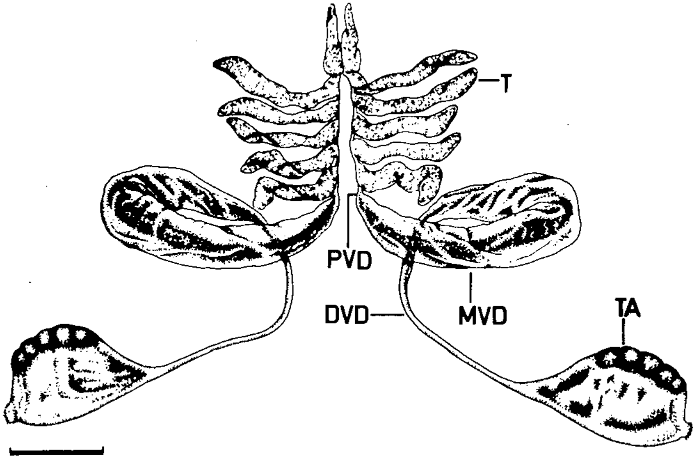

Fig. 8. Male reproductive system of *P. monodon*. T, testis; PVD, proximal vas deferens; MVD, medial vas deferens; DVD, distal vas deferens; TA, terminal ampoule. Scale represents 5 mm.

The terminal ampoule, a bulbous structure, possesses a thick muscular wall lined with extremely tall columnar epithelial cells. It has two chambers internally; one containing the spermatophores and the other, calcareous material of a slightly gray color. The paired terminal ampoules open at the base of the coxopod of the 5th pereiopods. The spermatozoon, a minute globular body, is composed of two parts: head and tail (Fig. 9). The head is large and almost circular in outline being about 3 microns in diameter, while the tail is relatively thick and short. Although it is logical to assume that the spermatozoon is capable of movement, the present author has never observed spermatozoa moving under a microscope at high magnification (x600).

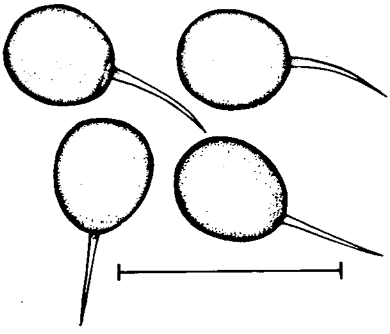

Fig. 9. Spermatozoa of *P. monodon*. Scale represents 5 microns.

The petasma is a pair of endopods of the 1st pleopods. It is formed by the interlocking of minute

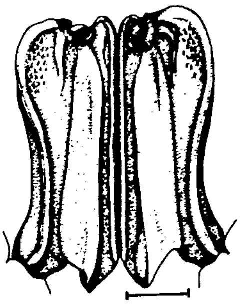

Fig. 10. Petasma of *P. monodon*. Scale represents 0.2 mm.

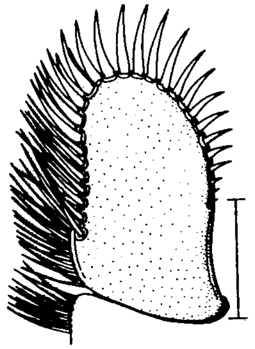

Fig. 11. Appendix masculina of male *P. monodon*. Scale represents 1 mm.

hook-like structures (Fig. 10).

The shape of appendix masculina which is located on the endopod of the 2nd pleopod is generally oval in shape (Fig. 11).

B. Female organ

The female reproductive system consists of paired ovaries, paired oviducts and a single thelycum; the first two are internal and the last is an external organ. The ovaries are partly fused, bilaterally symmetrical bodies extending in the mature female for almost its entire length, from the cardiac region of the stomach to the anterior portion of the telson. In the cephalothoracic region the organ bears a slender anterior lobe and five finger-like lateral projections. A pair of lobes, one from each ovary, extends over the length of the abdomen. The anterior lobes lie close to the esophagus and cardiac region of the stomach. The lateral lobes are located dorsally in the large mass of hepatopancreas and ventrally in the pericardiac chamber. The abdominal extensions lie dorso-lateral to the intestine and ventro-lateral to the dorsal abdominal artery.

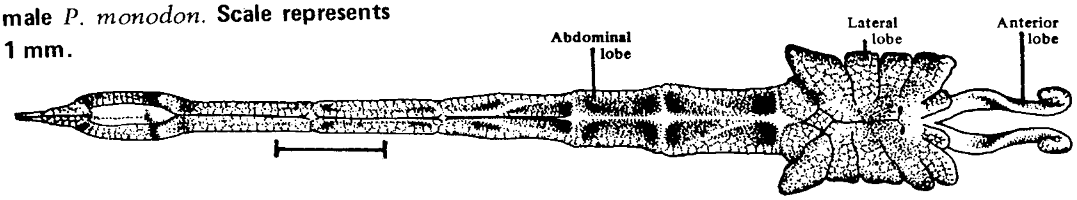

Fig. 12. Ovary of *P. monodon*. Scale represents 20 mm.

The oviducts originate at the tips of the 6th lateral lobes and descend to the external genital apertures hidden in the ear-like lobes of the coxopods of the 3rd pair of pereiopods.

The thelycum is located between a pair of the 5th pleopods and consists of an anterior and a pair of lateral plates. (Fig. 13).

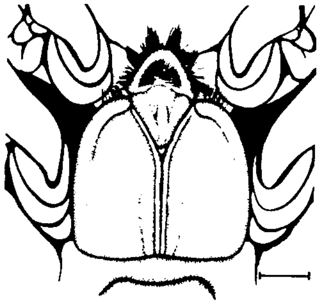

Fig. 13. Thelycum of *P. monodon*. Scale represents 0.2 mm.

Discussion

The genital organs of both sexes of *P. monodon* are, from the morphological point of view, principally the same as those of *P. setiferus* (King, 1948) and *P. indicus* (Subrahmanyam, 1965). However, in detail, there are some differences as follows:

a) The testis of *P. monodon* consists of six lobes (one anterior and five lateral), while *P. setiferus* possesses a pair of single short posterior lobe in addition to five lateral lobes, and *P. indicus* has only four lateral lobes.

b) The spermatozoa of *P. monodon* composed of a head and short tail are similar to those of *P. japonicus* (Hudinaga, 1942), *P. indicus* (Subrahmanyam, 1965) and *P. duorarum* (Cummings, 1961), but differ from those of *P. setiferus* (King, 1948) which possess a middle piece in addition to the head and tail.

VI-2 Copulation and function of external genitalia

King (1948), Eldred (1958) and Pérez Farfante (1975) presented some hypotheses concerning the transfer of spermatophores to the thelycum in *P. setiferus, P. duorarum* and several *Litopenaeus* species, respectively. However, no satisfactory explanation as to how the organ function in both male and female has been made.

In this part, a more or less comprehensive hypothesis on the role of each genital organ during copulation and impregnation is presented, basing mainly on the postulate that every organ or organ part has some functional basis. A tentative explanation of the mechanism of sperm transfer during copulation is here possible, based on close examination of the male and female external genitalia and referring to Primavera's (1979b) observations on courtship and mating behavior in the said species in captivity.

Description

The following sequence of events in the mechanics of sperm transfer is suggested. Preparation for copulation probably occurs with courtship behavior immediately after molting of female, and when male and female swim parallel to each other (Fig. 14A) (Phase I, Primavera, 1979b). During this phase the male bends its body in order to facilitate the forward swinging of the second pair of pleopods. At the same time the first pair of pleopods together with the compound petasma stretches and points vertically down. In this position, the numerous strong spines lining the outer border of each appendix masculina are able to catch into the respective side wing-like structure of the posterior proximal margin of the petasma. With a certain

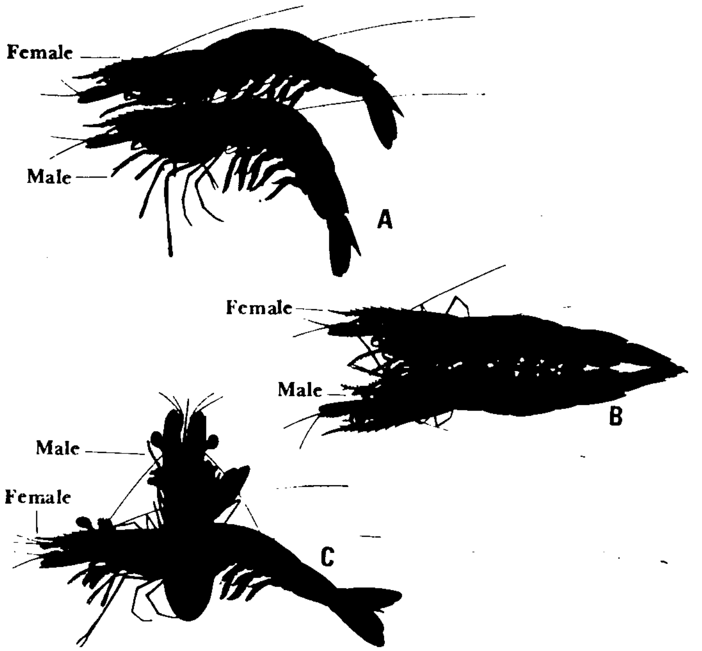

Fig. 14. A, *P. monodon* in parallel swimming position; B, *P. monodon* in abdomen to abdomen position; C, *P. monodon* in perpendicular position with male curving body around the female. Drawings modified after Primavera (1979b).

manipulative movement the appendix masculina is able to set off the unzipping of the numerous minute interlocking petasmal hooks from this portion (Fig. 15A). Once a portion is separated the first pair of pleopods then stretch out laterally pulling the petasmal halves apart. As observed from manual separation of the petasma components it can be assumed that due to the very effective and zipper-like function of the minute hooks the animal itself cannot separate the petasma into its two component halves by the pleopod muscle if not assisted by the appendix masculina which acts as an unzipping trigger. King (1948) suggested that the appendix masculina possibly aids in the transfer of spermatophores during copulation. In view of the structure, size and position of this organ the author disagrees with King's (1948) idea.

With the male body still slightly bent and the petasma already biparted, the relatively stiff hook-like structure at the anterior distal end of each petasmal component finds its way into the slit-like orifice of the terminal ampoule on the coxa of the respective 5th pereiopod (Fig. 15). Since this procedure cannot be directly controlled by the animal, it is more of a trial and error. It should be noted, however, that once the petasma is separated into two halves, the organ no longer lies more or less parallel to the ventral side of the animal. The loss of tension exerted on the united petasma by the pair of pleopods, automatically allows the petasmal halves to turn slightly vertical to the animal's body with the pointed hooks facing the animal's body. The position of the respective hooks and the terminal ampoules on both sides is such that the posibility of the hooks "accidentally" clawing into the slits of the latter is very high. In separated petasma these hooks cannot accidentally come into contact with the terminal ampoules since they are facing each other and are close together. Although both hooks need not find its mark it can be expected that only one successful puncture of the terminal ampoule would be sufficient for the accomplishment of copulation. Upon reaching this preparative procedure the male is ready to take the abdomen-to-abdomen position with both male and female ventral side attaching to each other (Fig. 14B) (Phase 2, Primavera, 1979b). With the petasmal hook(s) still firmly anchored to the terminal ampoule(s) the male stretches out and the terminal ampoule is ripped. Due to the distortion and tension exerted on the ampoule the spermatophore is then forcibly discharged through the orifice or the ruptured hole.

In this stretched out position (Fig. 14B) the spermatophore is prevented from loss or spillage by the two lateral walls formed by the two component halves of the separated petasma. In the case of a male and female belonging to a similar size range, this abdomen-to-abdomen position would bring the spermatophore directly over the thelycum region. While still hooked on to the terminal ampoule(s) the thickened and relatively strong calcified margin of the ventral lobule of the petasma component finds its way into the narrow groove between the raised triangular median plate of the thelycum and the knob-like protuberance at the base of the coxopod of the 4th pereiopod of the female (Fig. 16). The role of the coxal plates in the retention of compound spermatophores in certain species has been well described and illustrated by Pérez Farfante (1975). In *P. monodon,* however, this position is replaced by the petasma itself. By pressing the legs together, the female is capable of holding the petasma tightly in place. Despite the soft-shelled condition of the female during copulation it can be assumed that the coxal plates and the median plates of the thelycum are still relatively firm as compared to other portions of the thelycum. The petasmal halves form the lateral walls between the male and female bodies. In this enclosure, loss of sperm is duly prevented or greatly minimized.

Shortly thereafter, the male turns perpendicular to and curves its body around the female, taking the Phase 3 position (Fig. 14C) (Primavera, 1979b). With the male body bent again, the petasmal components could unhook themselves from the terminal ampoule (s), but remain fixedly held in place to the female. Such tight hold in effect brings the partly free two components close together, enough for the minute hooks lining both median sides to get automatically snagged together again. The reformed united petasma now completely encloses the spermatophore which now lies directly above the thelycum. The perpendicular turning of the male causes the flexible petasma to be greatly distorted. The spermatophore is therefore squeezed through the V-shaped fissure of the left and right lateral plates of the thelycum and becomes deposited in the hollow-spaced seminal receptacle. This procedure probably occurs with the flicking action observed at the end of the copulation (Fig. 14C) (Phase 3, Primavera, 1979b). The small teethlike structures which are pointing anteriorly and lining the lateral lobes of the petasma might also assist in preventing the spermatophore to spill out posteriorly under the pressure. The female soon eases pressure of its 4th pair of pereiopods and the petasma is set free. The two animals separate and copulation ends.

Although it seems logical to conclude that because of the male and female position in mating, sufficient intimate contact of male genital pore and female thelycum cannot be achieved, an external copulatory organ for the manipulation and successful insertion of spermatophores is therefore needed. Of interest, however, is the function of the minute hooks lining the median border of both petasmal components, which makes direct interlocking possible. This interlocking cannot be broken easily but can be restored with minimum effort. With only slight pressure the numerous hooklets engage into each other forming a tight bond. Above all such mechanism makes repeated joining or separation possible. The apparently united petasma components therefore remain an open ring which facilitate the molting process. Examination of the cast-off exoskeleton has shown that the petasma exoskeleton remains joined together as the animal simply slipped out of it as separated components, to be joined together again as the new chitinous skeleton hardened.

Molting process is, however, not the only explanation for the presence of interlocking mechanism. The presence of appendix masculina suggests that the petasma must at certain times function as a single unit and at another time as a binary organ as mentioned above.

Discussion

Since impregnation apparently takes place shortly after the female had molted, it seems more appropriate to assume that during Phase I (Fig. 14A) it is the hard-shelled male which positions itself above the soft-shelled female and that during Phase 2 (Fig. 14B) it is the male which manipulately turns the female ventral side up in contrary to Primavera's observation.

While it is assumed that in *P. monodon,* the thelycum of the female and the petasma and appendix masculina of the male function as copulatory organs, their actual role in this activity can never be observed nor demonstrated in live specimens. The mating action is usually brief (Bauer, 1976; Primavera, 1979b), and the view to the organs is obstructed by the animal's body and extremities. This implies that even the use of cinematography will not completely eliminate this problem. The author feels that the use of fragmentary data to create a certain hypothesis as such is still potentially fruitful, as it will actively encourage certain important kinds of investigations which can be tested by actual data and which if confirmed could become significant generalizations that are far more valuable than an unending number of unrelated observations. Even should none of the generalizations ultimately hold, the work of disproving them will provide important information that would probably be obtained in no other way.

Basing on Andrew's (1911) idea, that a comparative study of the copulatory organs may help in the proper classification of the Crustacea, a theoretical possibility is envisioned. Bauer (1976) stated that in advanced brachyuran, fertilization is internal while in primitive ones it is external. According to him in *Heptacarpus pictus,* the spermatophore consists of only glutinous structures which are deposited on the 1st abdominal sternite of the female; there are no structures on this smooth sternite to receive the spermatophore, which is due to its adhesive nature, will cling to any object and it comes into contact.

According to Pérez Farfante (1975), in primitive brachyurans, the structural spermatophore is simply plastered to the sternite or in a ventral thoracic groove. This means that although the spermatophore is protected by a calcified structure, it is still subjected to the surrounding waters and may be dislodged or retained for only a short time after mating. In advanced brachyurans, the spermatophore occupies a special receptacle within which the spermatophore may lie safe for a longer period. The capability of the female to retain the spermatophore by many types of thelycum structure can provide vital information on the ecology and biology of the animals, such as time of spawning after copulation. Theoretically it can be expected that with the same degree of successful propagation, the time of spawning after copulation must be shorter in primitive groups than in advanced ones.

Bauer (1976) has shown from experiments that the copulatory structures of male *H. pictus* are not absolutely essential for sperm transfer, but they assist in the transfer of the spermatophores and help to increase the probability of their reaching the correct position on the female. In *P. monodon,* however, it can be assumed that removal of one or other organ parts would result in unsuccessful copulation. Complexity of the copulatory organs is thus an evolutionary adaptation of increased protection for the sexual production one hand and ensuring successful impregnation on the other. In other words, comparative study of the structure and function of copulatory organs might lead to another source of criteria useful in classification of crustacean.

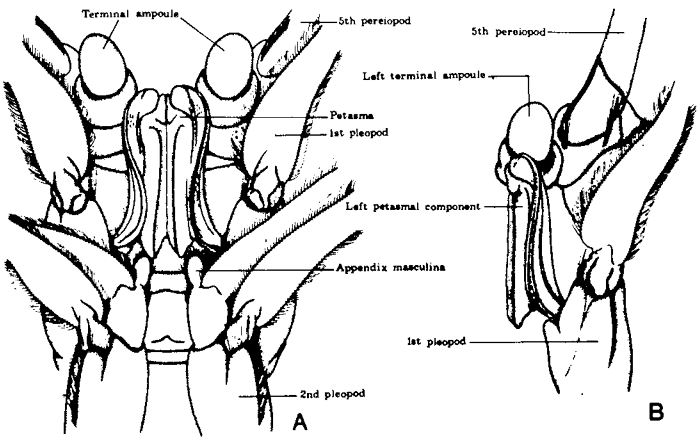

Fig. 15. A, Unzipping of petasmal components by the appendix masculina during Fig. 14A position. B, Left petasma half in hooked position in the orifice of the terminal ampoule during Fig. 14A or B position.

Providing that this paper is basically correct, it can be assumed that similar functional properties would hold true for other penaeid species with similar configuration of reproductive organs as *P. monodon.* It is hoped therefore, that this study will be of some use as guideline for future investigation.

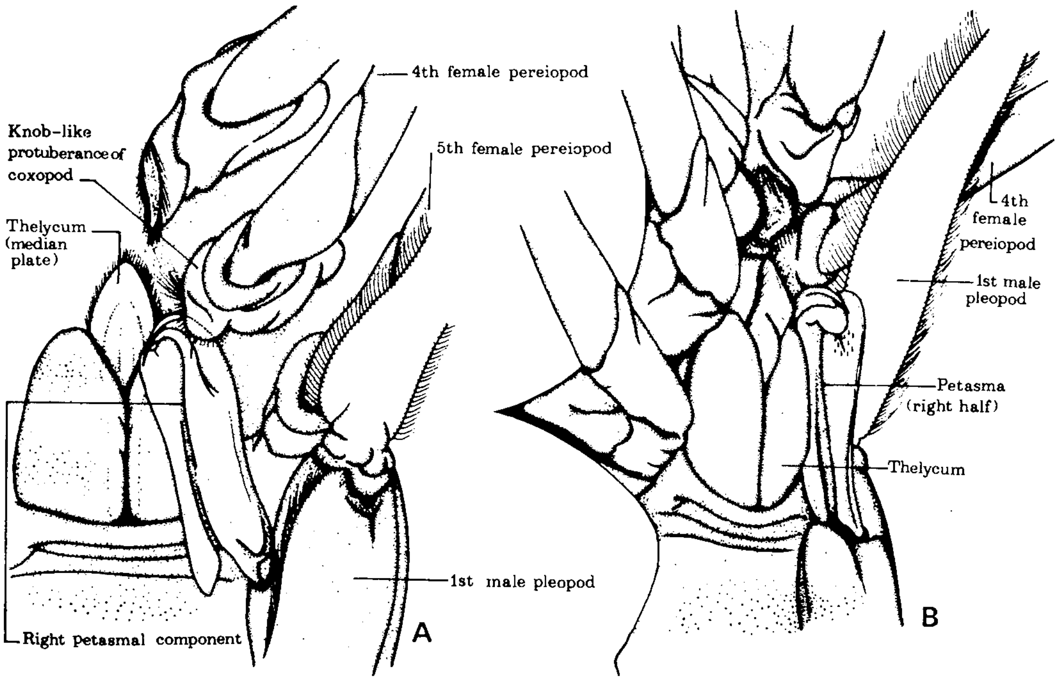

Fig. 16. A, Right petasma component being held in place between the median plate of the thelycum and the coxopod of the 4th pereiopod of the female. Position is Fig. 14B. B, Semi lateral of female's ventral side with petasma half forming one of the lateral walls over the thelycum. For clarification terminal ampoule and male body are omitted in the illustrations. Position is Fig. 14B.

VI-3. Ovarian development

The maturation process has been arbitrarily categorized into five successive stages of a development, based mainly on ovum size and gonad expansion plus the color for the purpose of describing the degree of sexual maturity.

Categories 1 and 5. Undeveloped and spent stages (Figs. 17A and 18A)

Ovaries are very small, flaccid, and invisible through the exoskeleton. The ova are covered with a layer of follicle cells and are small, measuring 35 microns on average, and only the largest ones reveal a nucleus and yolk granules. *P. monodon* with carapace length less than 47 mm, are recognized as undeveloped.

Category 2. Developing stage (Figs. 17B and 18B)

Developing ovaries can be easily differentiated from other tissues. They are flaccid and white to pale olive buff. Developing ova have yolk granules and cells believed to be nutritive bodies and have an average diameter of 177 microns.

Category 3. Nearly ripe stage (Figs. 17C and 18C)

This stage may be determined with certain accuracy in the field because fresh ovaries have a glaucous color and are visible through the exoskeleton and are large and turgid, particularly the portion at the 1st abdominal segment. The average size of ova is 215 microns.

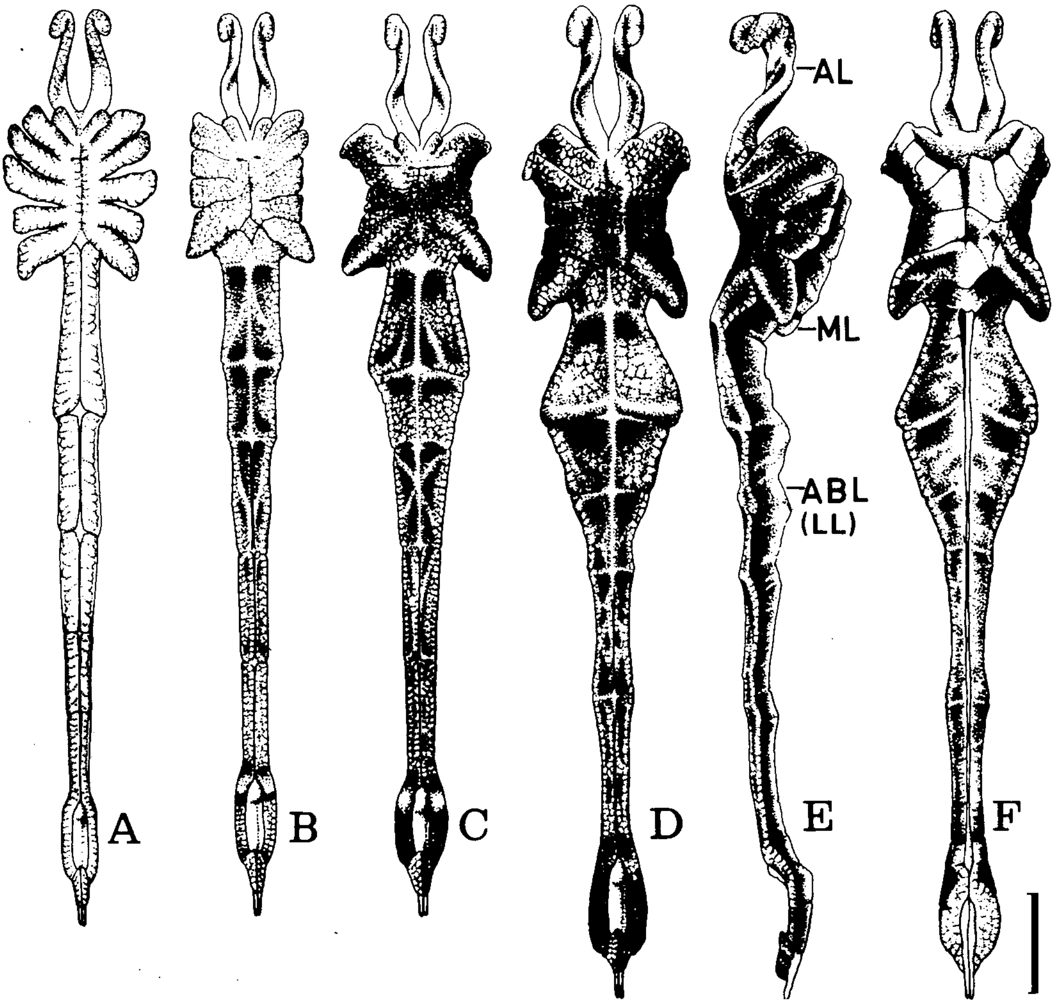

Fig. 17. Ovarian development of ***P. monodon.*** **A, Undeveloped and/or spent stage (dorsal view); B, developing stage (dorsal view); C, nearly ripe stage (dorsal view); D, ripe stage (dorsal view); E, lateral view of D; F, ventral view of D; AL, anterior lobe; ABL, abdominal lobe; (or LL, lateral lobe). Scale represent 20 mm.**

Category 4. Ripe stage (Figs. 17 D-F and 18D)

The ripe (mature) stage is recognized only by the presence of a characteristic margin of peripheral rod-like bodies, the apexes of which appear to radiate from the center of the egg. This is the final stage before the actual spawning, since prawns at this stage contain the largest ova encountered with an average size of 235 microns. Literatures on other *Penaeus* spp. reported the presence of peripheral bodies as indicative of the mature stage (Hudinaga, 1942; King, 1948; Subrahmanyam, 1965; Liao, 1973).

Discussion

In the field, the selection of spawners is usually based on changes in color, the relative size (particularly that under the 1st abdominal segment), texture, and turgidity of the ovary observed through the exoskeleton in order to identify them quickly. Using these criteria, it is impossible to differentiate between undeveloped and

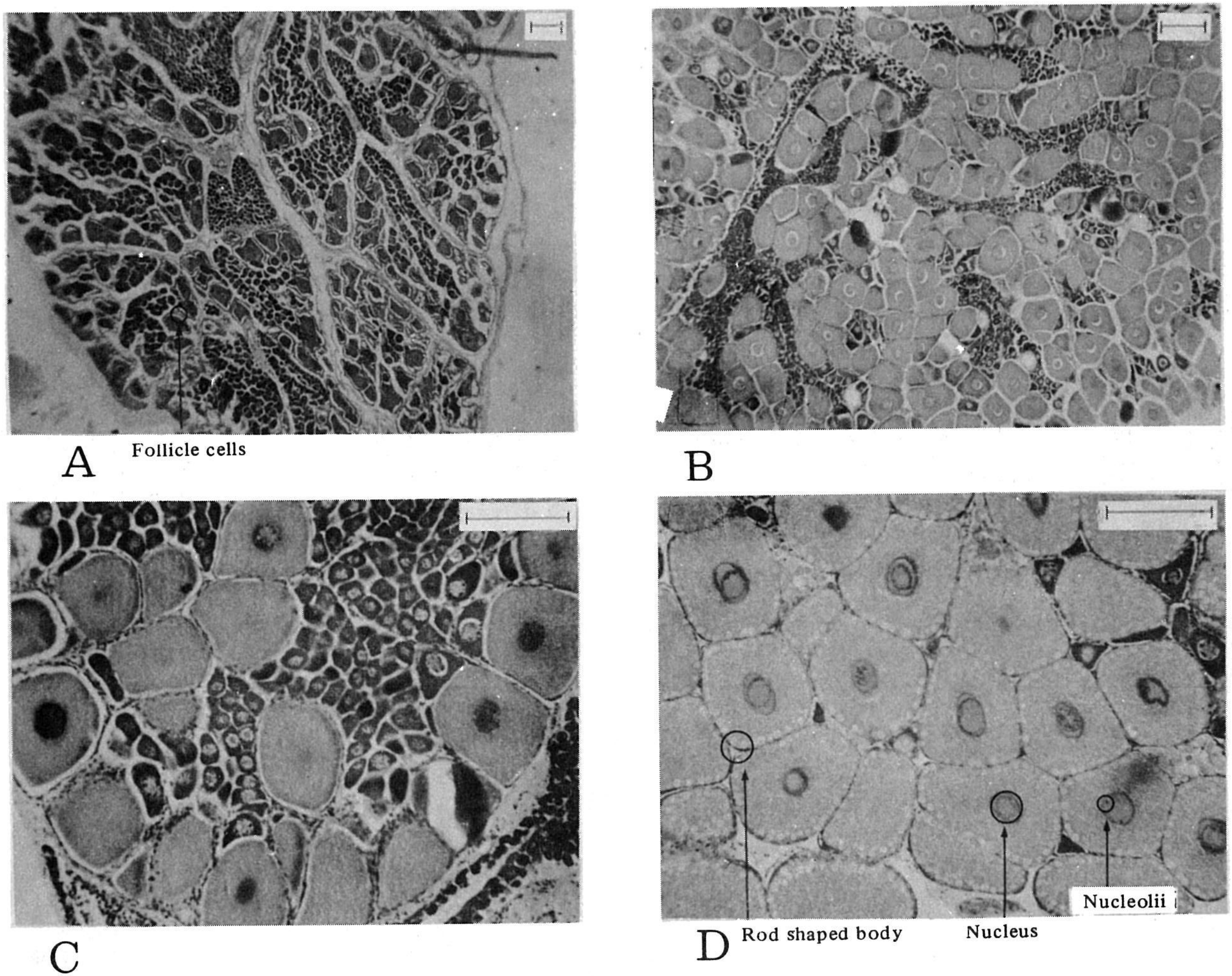

Fig. 18. Ovarian development of *P. monodon*. A, undeveloped stage; B, developing stage; C, nearly ripe stage; D, ripe stage. Scale represents ca. 0.2 mm.

spent stages (Categories 1 and 5, respectively), and between nearly ripe and ripe stages (Categories 3 and 4, respectively). Thus for the convenience of field activities, the ovarian stage may be classified into two categories: stage I involving undeveloped, developing and spent, and stage II nearly ripe and ripe stages, the latter utilizable in the hatchery as spawners when necessary.

There was no quantitative and qualitative difference found between ripe ovaries of the same sized prawns from fish corrals located in shallow water (at the mouth of the Batan bay) and those from commercial trawlers from deeper water (offshore). This finding suggests that the spawning of *P. monodon* takes place not only offshore but also near the mouth of the bay where offshore water penetrates. In other words, spawning does not require a particular water depth.

VI-4 Minimum size for sexual maturity

Sexual maturity was defined as the minimum size of *P. monodon* possessing spermatozoa inside the terminal ampoule in the males and inside the thelycum in the females. In the males the terminal ampoule was extracted with a pair of tweezers and was dissected to remove the whitish jelly-like substance containing the spermatozoa. In the females the lateral plates of the thelycum were removed first, then the whitish transparent substance was extracted with a pair of tweezers. A small amount of the extracted material was mounted on a glass slide and covered with a cover glass for examination of the spermatozoa under a microscope using high power magnification (X400). The extracted material was sampled and examined five times for each animal.

Result and discussion

A total of 813 individuals consisting of 395 males and 418 females ranging from 10 to 76 mm CL were examined.

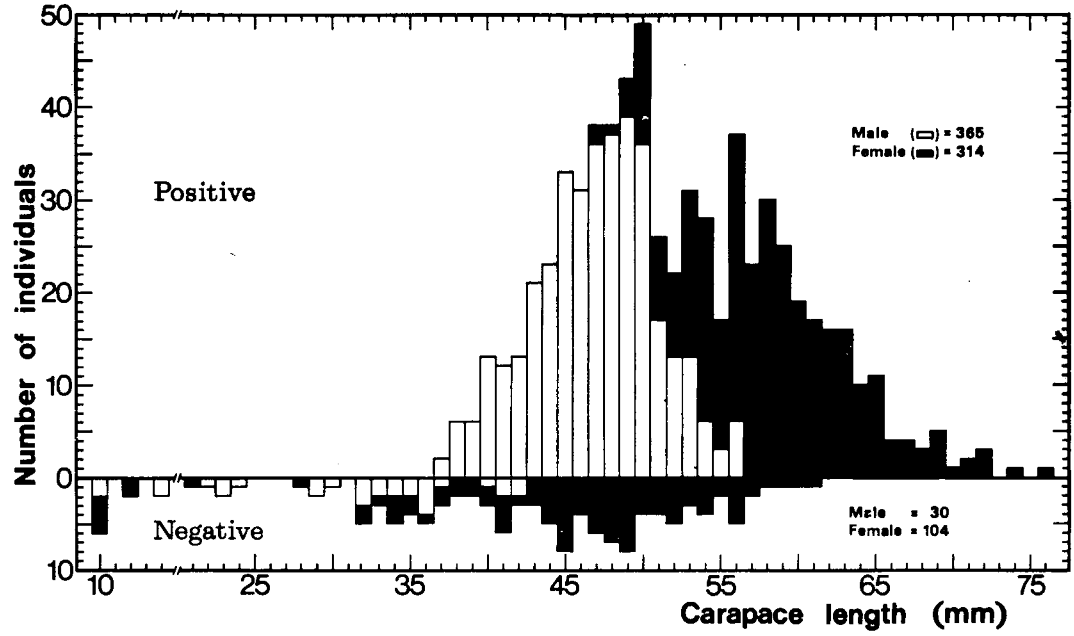

Fig. 19. Frequency distribution of spermatozoa occurrence in both sexes of *P. monodon* caught at Batan Bay from 1976 to 1979. Newly molted individuals are excluded.

The males of 37 mm CL and greater possessed spermatozoa except for six individuals accounting for 1.6 % of the samples. Most of females of 47 mm CL and greater had spermatozoa. However, even up to 61 mm CL, 54 females (14.7 %) did not possess them. The size at onset of sexual maturity in both males and females was independent of the fishing area and the season.

It is interesting to note that males are sexually mature at a smaller size than females by 10 mm CL in *P. monodon* from the wild. This phenomenon was also observed by Tuma (1967) reporting the minimum size of sexual maturity of about 25 mm CL in males and about 30 mm CL in females of *P. Merguiensis*. Ikematsu (1963) also showed that length at sexual maturity differed between the sexes and was 24 mm CL in males and 26 mm CL in females in *Metapenaeus monoceros* (as *M. ensis*), 21 and 24 mm CL in *Metapenaeus joyneri*, and 9 and 11 mm CL for short term generations and 12 and 16 mm CL for long term generations of *Trachypenaeus curvirostris*. This might be regarded as a general characteristic of penaeid prawns because male adults are generally smaller than females in size.

It is a curious fact that during examination of spermatozoa under a microscope, the spermatozoa obtained from smaller males (about 37 mm CL) seemed to have no tail portion, appearing as a single ball, the head portion only visible, whereas females and larger males possessed normally tailed spermatozoa. No final interpretation of this finding has yet been possible.

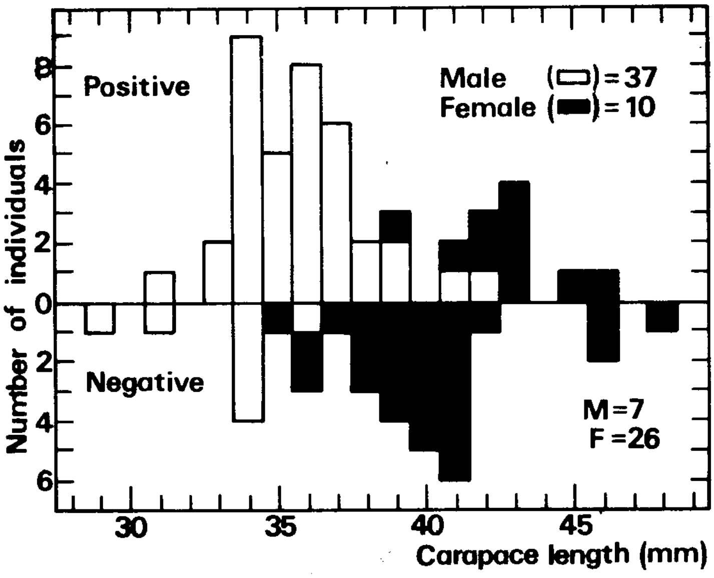

Fig. 20. Frequency distribution of spermatozoa occurrence in both sexes of *P. monodon* reared in prawn ponds, Iloilo.

Only six out of 371 males (1.6 %) with a carapace length 37 mm and greater lacked spermatozoa, which might be due to individual variation. However, 54 females out of 368 (14.7 %) of carapace length 47 mm and greater did not possess spermatozoa as shown in Fig. 19. This phenomenon suggests that adult females not possessing spermatozoa might be those which failed to copulate with male after molting under natural conditions, in addition to the individual variation.

It is also interesting to note here that there is a size gap between *P. monodon* from the wild and those from brackishwater fishponds in terms of possessing spermatozoa on both sexes. The minimum sizes of male and female possessing spermatozoa are 37 and 47 mm CL from the wild as mentioned, while 31 and 39 mm CL from brackishwater prawn ponds, showing smaller sizes from the ponds (Figs. 19 and 20).

Penaeid thelyca are divided into two general types, viz. open and close by Tuma (1967), and *P. monodon* belongs to the latter (Pérez Farfante, 1975). Tuma (1967) and Primavera (1979) mentioned that female penaeids with close thelycum must be in soft-shelled condition before receiving male spermatophores, and Tuma (1967) stated that unless females spawned during the time between insemination and their next molt, the entire spermatophoral mass is lost with the exuviae.

During this investigation all eight soft-shelled females of *P. monodon* observed had no spermatozoa, which is in agreement with Tuma's finding on *P. merguiensis.*

VI-5 Fecundity

For the estimation of fecundity, each spawning female was placed in a 1,300 *l* FRP tank containing 1,000 *l* of aerated seawater, and allowed to spawn. The following morning, when spawning was completed, the female was taken out. Before counting the eggs, the rearing water was agitated to ensure even distribution of the spawned eggs, and the number of eggs contained in a 1 *l* beaker was counted. The counting procedure was repeated more than 20 times by different people and in different areas of the tank to minimize the counting error. The number of eggs in the samples was then multiplied by the total volume of water to estimate the total number. Partial spawnings were not included.

A total of 37 spawning females out of 52 individuals tested spawned completely. Their carapace length varied from 53.1 to 81.3 mm, and the number of eggs from 248,000 to 811,000. The regression line between carapace length and the number of eggs released was derived by the least square method as follows:

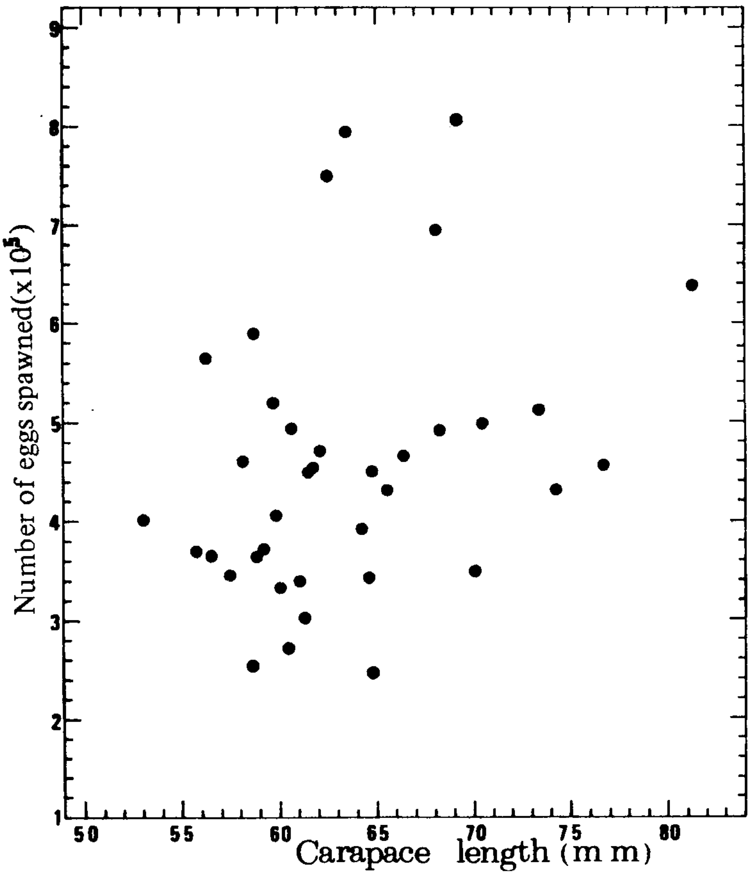

Fig. 21. A scatter plot showing the relationship between carapace length of female *P. monodon* and the number of eggs spawned in the laboratory.

$Y = 5802.43 + 7110.13 X$, where X is carapace length in mm and Y number of eggs spawned. The coefficient of correlation was low ($r = 0.3155$). However, applying t-test expressed as $t = \frac{r}{\sqrt{1-r^2}} \sqrt{(N-2)}$, where N is number of samples, it showed that r value is statistically significant ($t = 2.0727$, $df = 35$, $P < 0.05$).Thus it may be concluded that the number of eggs spawned increases as increment of carapace length. Further study by means of counting number of ovarian eggs will have to be carried out in order to ascertain the real fecundity of *P. monodon.*

VII. SPAWNING

VII-1. Spawning behavior

On November 21, 1975, the author was able to observe three instances of spawning of *P. monodon* in large glass aquaria. Five gravid females were introduced separately into aquaria containing about 80 *l* of seawater each. Three of them spawned at night, one at 2145 hours and the others at about 2230 and 2330 hours midnight.

While resting on the sandy bottom, the spawner suddenly became active, swimming in the water for about one minute, and then started to spawn while swimming very slowly in the upper or middle part of the water. During spawning, the last 3 pairs of pereiopods were held tightly together and flapped with an open and close movement, presumably to aid discharging eggs and spermatozoa, while strongly moving the pleopods for swimming. The eggs were extruded from the paired genital pores located at the base of the 3rd pereiopods while at the same time spermatozoa from the thelycum located at the base of the 5th pereiopods, looking like a greenish and whitish smoke blowing backward, respectively. It is believed that these discharged eggs are fertilized in the water owing to turbulence generated by the forward and backward movements of the pleopods. As a result, the movement of the pleopods seems to aid not only to swim but also to fertilize the eggs spawned. The fertilized eggs remain suspended in the water for a few minutes making the aquarium water turbid, and then gradually sank to the bottom. The time required for each spawning was approximately two minutes. In spite of the strong light required for taking pictures, they did not stop spawning. After spawning they rested on the bottom but did not appear to be weakened.

In addition to the observations described above, more than 20 cases of spawning under laboratory conditions have been followed by means of the examination of the extent of egg development under a microscope the following morning. Based on these data, spawning takes place mainly between 2200 and 0300 hours.

Weymouth *et al.* (1932) believed that *P. setiferus* dies immediately after spawning, while Hudinaga (1942) reported that the spawning action of *P. japonicus* did not seem to weaken the spawner.

According to the present observation of the spawning and larval rearing, most of the spawners of *P. monodon* survived more than 10 days under laboratory conditions after spawning. Furthermore, some of them successfully molted within a few days after spawning. Hudinaga (1942) suggested that prawns sometimes die following the spawning, particularly in the case of *P. orientalis.* More work on this matter needs to be carried out before evidence, particularly to estimate the number of spawnings as well as the life span of spawning females.

VII-2. Size distribution of spawner

A total of 652 spawning females ranging from 48 to 81 mm CL were measured.

The spawning females from Tigbauan and Himamaylan are generally larger than those from Batan. The frequency distribution of carapace length by area is shown in Figs. 22 and 23.

The spawning females from each area showed modal carapace lengths of 50, 62 and 70 mm CL at Tigbauan, 48, 60, and 66 mm CL at Himamaylan, and 62, and 72 mm CL at Batan, respectively, from which it would appear that there may be four size groups of spawning females viz. 48-50, 60-62, 66 and 72 mm CL as shown in Fig. 22.

According to the SEAFDEC prawn collectors at Tigbauan and Himamaylan, the smaller spawning female, viz. 48 to 58 mm CL were mainly caught in shallow

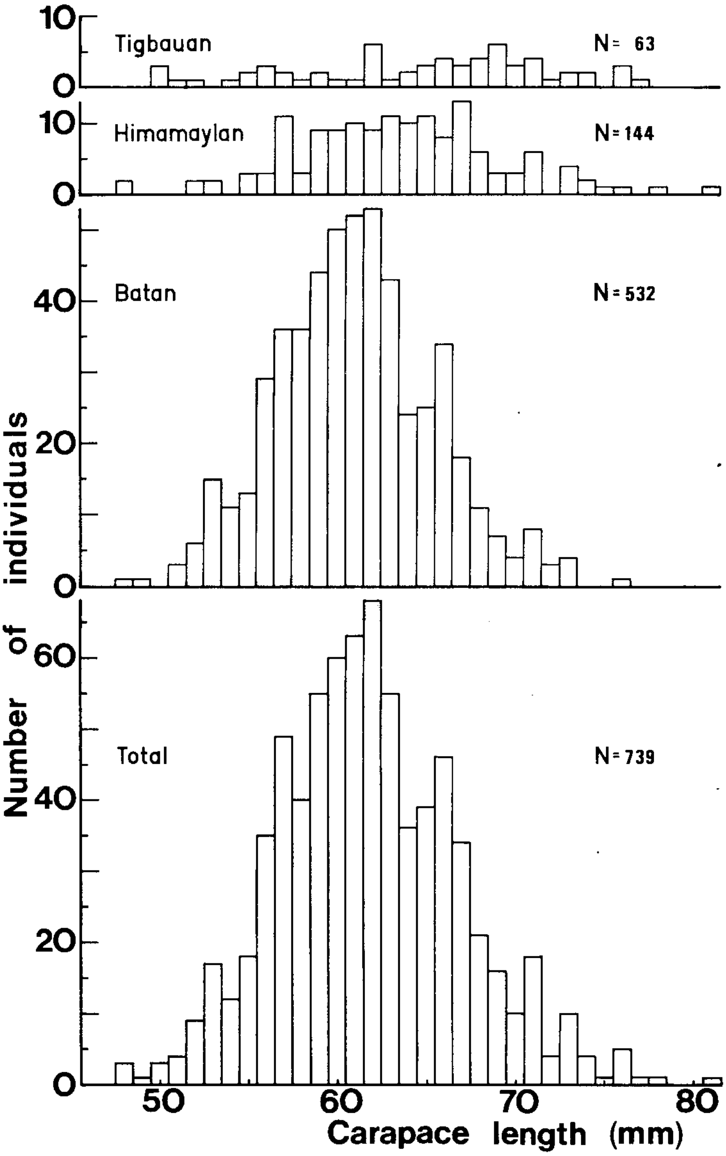

Fig. 22. Size distribution of the spawner of *P. monodon* from three areas.

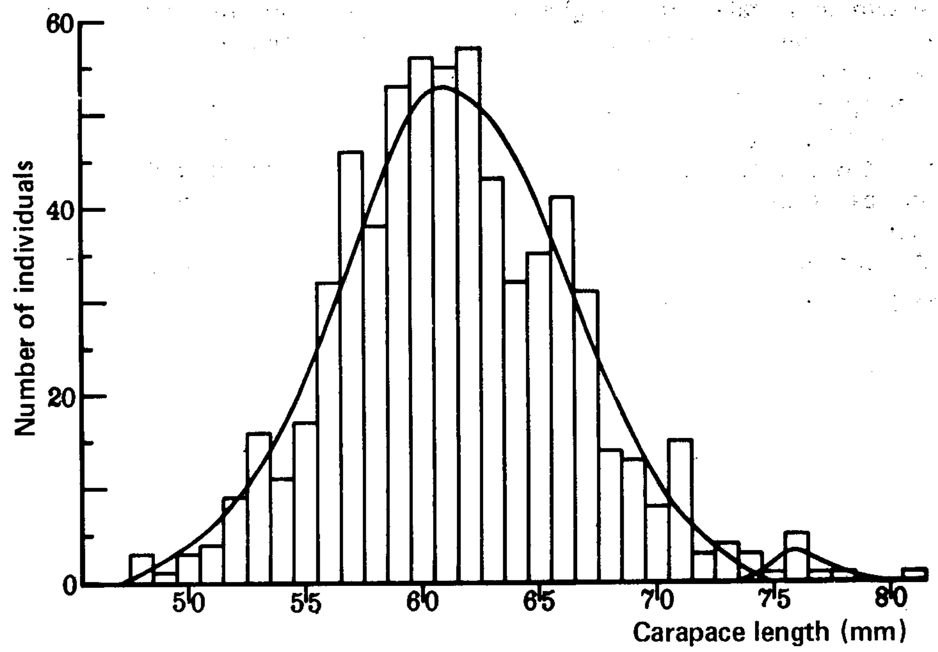

Fig. 23. Size distribution of the spawner of *P. monodon* with 2 normal curves, derived from Fig. 22.

waters by small trawlers, while the larger ones were obtained from deeper water by big trawlers, although catching effort per area differs.

Although the survival rate of adult *P. monodon* in the wild might be poor, Fig. 22 may suggest that the adult females might spawn four times within their life span at carapace lengths of approximately 50, 62, 66, and 72 mm CL. This interpretation is based partially on the findings of the present study (p. 96) and Chao (1971), showing 5-10 % increment of carapace length per molting. However, a statistical treatment using more specimens was not accomplished yet, thus further study by means of rearing experiment under laboratory conditions as well as the tagging experiment in the field is highly needed to get the final conclusion.

Judging from Fig. 22, it would appear that most of the spawners from the mouth of Batan Bay are smaller (62 mm) than those found offshore at Tigbauan (70-72 mm) and Himamaylan (64-66 mm). This phenomenon could be explained as the migration of the spawners from shallow to deeper waters with a greater proportion of younger females spawning in shallow water. Furthermore, the spawners from Batan Bay consist mainly of younger or first time spawned ones while those from Tigbauan and Himamaylan are mostly older and have previously spawned.

VII-3 Seasonal abundance of spawner

The main objective of this part is to ascertain the seasonal abundance of spawners (spawning females) of *P. monodon*.

Prawns were captured by means of fish corrals of private operators situated at the mouth of Batan Bay, or were trawled by R/V "SEAFDEC I" and "SEAFDEC II" off Tigbauan. To eliminate variation in catches attributed to the phase of the moon, prawns were collected once a month three days either side of the new moon period.

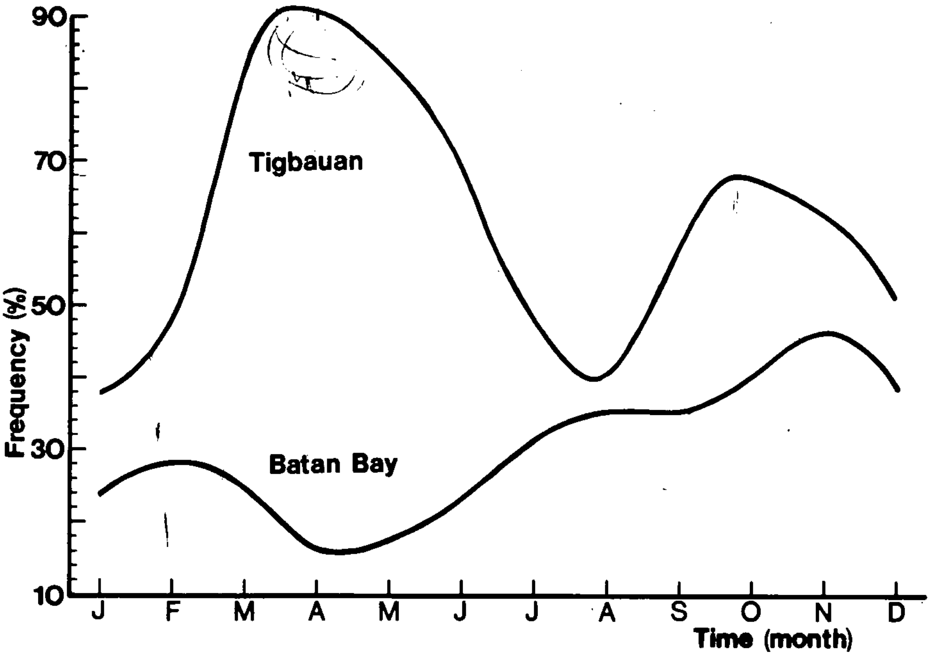

Fig. 24. Monthly occurrence of the spawner of *P. monodon* from 1976 to 1979.

The gonadal maturity of females was determined by examining the development of the ovarian lobe as viewed through the dorsal epidermal skeleton (see VI-3).

Water temperature and salinity during the survey period near bottom layers (3 to 5 m deep) at Batan Bay and 6 to 60 m deep off Tigbauan were recorded. Water temperature varied from 26.1 to 30.5 °C at Batan Bay and 27.1 to 30.1 °C off Tigbauan, whereas the salinity was between 27.1 and 34.6 °/oo at Batan and 27.5 and 35.5 °/oo off Tigbauan.

A. Batan Bay

Based on the examination of 560 females caught, 158 were spawners, making an average of 28.2 %. According to the results shown in Fig. 24, there might be two peak occurrences of spawning females, viz. February or July and November, although the spawners appeared all the year round with considerable seasonal variation from year to year.

B. Tigbauan

Based on the examination of 70 females trawled, 45 were spawners, making an average of 64.3 %. There seems to be two peak occurrences, viz. March and October. although the spawners appeared all the year round with considerable seasonal variation in its peak (Fig. 24).

According to weather records from Roxas City (near Batan Bay), Iloilo City, and Tigbauan, the period from January to April is a dry season, while June to October, rainy season. Thus the spawner occurrence may be triggered by the decrease or increase of water temperature as well as the fluctuation of salinity. It is interesting to note that the dry season involves one peak occurrence, and the rainy season has also one peak occurrence of the spawner (Figs. 24 and 25).

The Tigbauan area (offshore) showed a higher number of spawner occurrence (64.3 %) than that at Batan Bay (28.2 %). This phenomenon suggests that the main spawning ground is located offshore with deeper water, while the shallow area such as the mouth of Batan Bay is secondary.

VII-4 Spawning area

On the basis of the occurrence of spawners and larval stages: protozoea, mysis and megalopa (Fig. 27), the spawning is presumed to take place mainly offshore (outer littoral area) where water depth varies from 20 to 70 m within fully saline water (33-36 °/oo), and partly at the mouth of the bay mixed with offshore water.

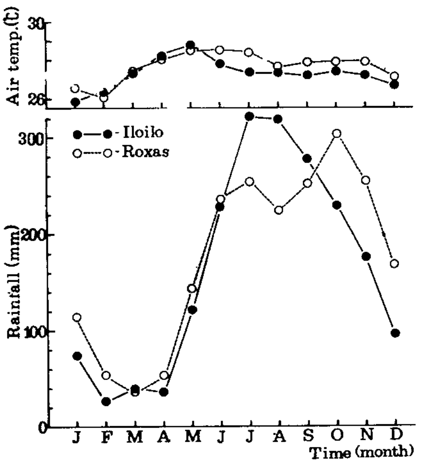

Fig. 25. Monthly fluctuations of air temperature and rainfall, based on 20-year data.

It is widely known that temperature is a triggering mechanism for the spawning of many invertebrates. In fact, the places where spawners were caught had consistently lower temperatures varying from 27 to 29 °C, unlike shallow brackish-water area. Regarding the relation of spawning to water temperature in *P. duorarum,* Eldred *et al.* (1965) stated that rising temperatures seem to be the most important factor in spawning, whereas Idyll and Jones (1965) indicated that spawning intensity is affected mostly by the absolute temperature changes.

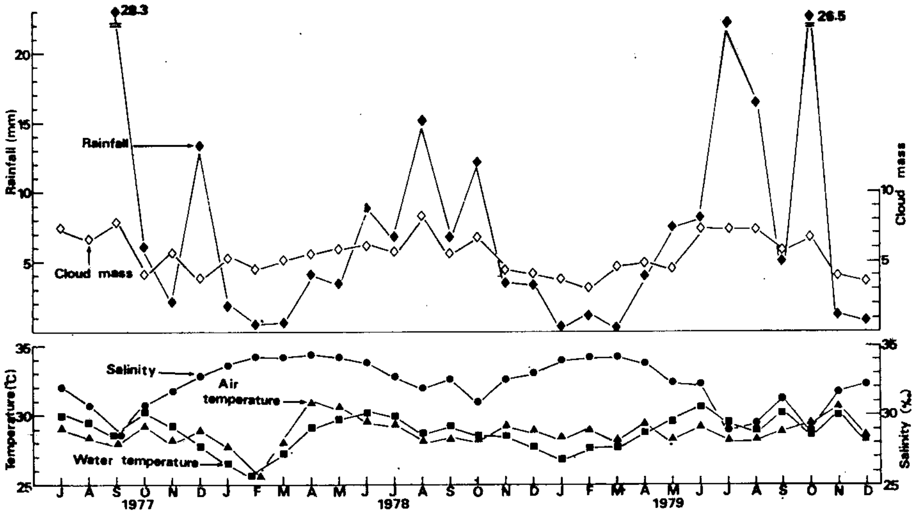

Fig. 26. Monthly fluctuations of rainfall (per day), cloud mass, water temperature, and air temperature, based on daily records at 0900 hours, Tigbauan.

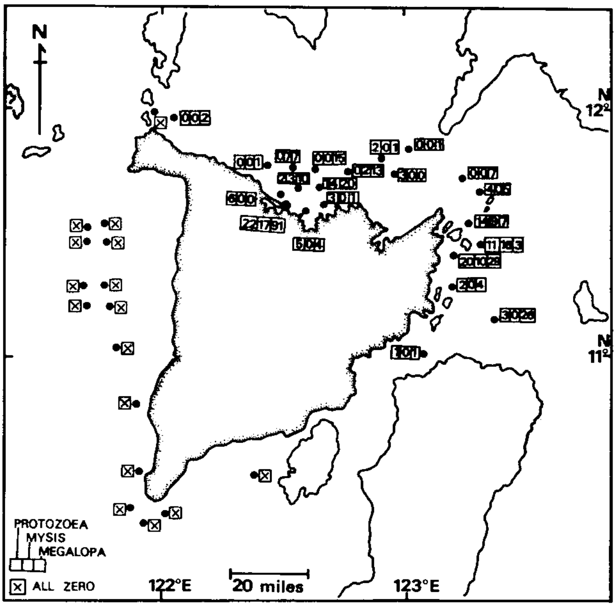

Fig. 27. Map showing distributions of protozoea and mysis of genus *Penaeus* and megalopa of *P. monodon.* Catching effort at the mouth of the bay is much greater than other sampling stations.

Fig. 28. Map showing soil sampling stations. Alphabets correspond to those in Table 1. (... *spawner collecting sites)*

Table 1. Analyses of the soil sampled in the various habitats of *P. monodon* inside and outside of of Batan Bay.

			CLASSIFICATION (%)					
Area	Gravel	Very Coarse sand	Coarse sand	Medium sand	Very fine sand	Silt	Clay	Coloration
			SIZE (mm)					
	>3.36	>1.00	>0.50	>0.21	>0.105	>0.053	>0.053	
A. Nursery area	0.00	0.57	0.42	1.65	16.55	17.42	63.39	Black
B. Middle portion of the bay	8.22	8.91	6.09	27.98	35.83	9.27	3.70	Brown
C. Center of the mouth of the bay	50.21	39.54	2.96	2.89	1.40	0.19	2.81	Whitish Brown
D. Deeper protion of the bay	0.00	0.92	0.92	8.44	24.43	12.95	52.34	Brown
E. Fishing ground (spawning area)	0.00	0.00	0.10	11.90	77.60	6.40	4.00	Gray

It was observed during the present study that the offshore spawning areas have in general a muddy substratum containing decaying organic matter in which prawn may gain protection by burrowing (Table 1).

Judging from the hydrography of the spawning areas, they are mostly located adjacent to deep waters where the seabed slopes steeply, e.g., Ragay gulf, Batan Bay, and Panguil Bay (Fig. 109). These conditions may thus provide relatively cold or warm water constantly, and may generate currents which contribute egg and larval transportation inshore.

In general, the spawning area seems to be located offshore relative to the nursery ground. Furthermore, the areas may be within the waters which are affected by tidal currents carrying inshore water. Based on the distribution of spawners and the larvae, the spawning area thus may be located quite close to the shoreline, mostly within 50 km unlike that of *P. setiferus* for which there is some 2,000 km between the spawning area and the shoreline (Lindner and Anderson, 1956).

VIII. DEVELOPMENT

On October 26, 1977, one gravid female of *P. monodon,* 207 mm in body length, was trawled by R/V "SEAFDEC II" off Tigbauan.

Spawning took place at about 0245 hours on the following day. Cultured unicellular diatom, *Ch. calcitrans* was introduced from the 1st protozoeal stage, and *Artemia* nauplii were fed from the 3rd mysis stage. Water temperature ranged from 26.9 to 29.0 °C, and salinity from 29.5 to 34.2 °/oo.

All the measurements were taken under a microscope with the aid of an ocular micrometer. Carapace length was measured, in the case of larvae (except megalopa), from the tip of rostrum, if present, to the mid-posterior end of carapace. Carapace width was sometimes taken at the point of greatest width across the dorsal or ventral surface.

Some megalopa and juvenile stage of *P. monodon* were collected from the shore waters by means of triangular nets or from mangrove canals by fry lures in Batan Bay. Furthermore, adolescent, subadult and adult are caught at the bay and offshore. In addition, some of them were obtained from brackishwater prawn ponds, Iloilo.

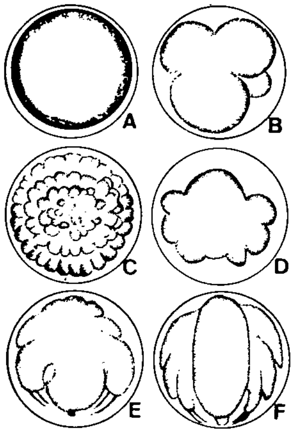

Fig. 29. Eggs of *P. monodon* at various embryonic developmental stages. A, newly spawned egg; B, 4-celled stage (about one hour after spawning); C, morula stage (about 1.8 hours after spawning); D, early embryonic nauplius; E, late embryonic nauplius; F, embryonic nauplius about to hatch.

VIII-I. Embryo

Viable eggs of *P. monodon* are spherical, yellowish green in color and somewhat translucent, ranging from 0.27 to 0.31 mm with an average of 0.29 mm in diameter (Fig. 29). The eggs sink slowly in still seawater to the bottom. There was a slight increase in egg size from newly-spawned ones, to just prior to hatching. The 2-celled, 4-celled, morula and embryonic nauplius stages were approximately 0.5, 1, 1.8 and 11 hours after spawning, respectively. Before hatching, the nauplius in each egg was observed to move intermittently.

VIII-2. Larva (excluding megalopa)

First nauplius

The 1st nauplius measures from 0.30 to 0.33 mm in total length with an average of 0.32 mm, and from 0.18 to 0.19 mm in body width with an average of 0.19 mm (Fig. 30). An ocellus which is retained in subsequent naupliar substages, lies on the longitudinal axis of the body near the anterior end. The body is darkbrown, opaque and pyriform in outline when viewed dorsally or ventrally. A pair (1 +1) of spines, one-half or one-third the length of the body, extends from the posterior margin of the body.

There are three pairs of appendages: the 1st antennae, the 2nd antennae and the mandibles. The 1st antenna is uniramous, bears one long and two moderately long lateral, two long and one short terminal setae. The 2nd antenna is biramous, the endopods bears two (rarely one) moderately long lateral and two long (rarely plus one small) terminal setae, the exopod is somewhat longer than the endopod and bears three long lateral, two long and one small terminal setae. The mandible is biramous, much shorter than the other appendages, and bears three long terminal setae on the endopod and one long sublateral and two long terminal setae on the exopod. It remains unchanged throughout the naupliar stage. The furcal spine formula is 1+1. Swimming is effected primarily by means of the first two pairs of appendages and supplementarily by means of the third pair.

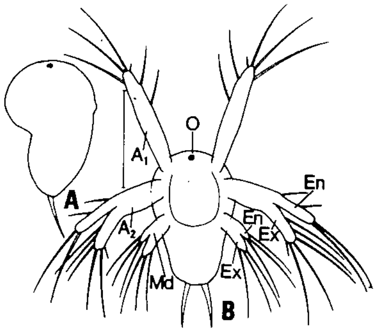

Fig. 30. First nauplius, lateral (A) and ventral (B) views. A_1, first antenna; A_2, second antenna En, endopod; Ex, exopod; **Md,** madible; O, ocellus. Scale represents 0.2 mm.

Second nauplius

The 2nd nauplius measures from 0.31 to 0.38 mm in total length with an average of 0.35 mm, and from 0.17 to 0.22 mm in body width with an average of 0.19 mm (Fig. 31). The major difference between the 2nd and 1st nauplius is that most of the long setae on each appendage become plumose. The shape of the body is generally similar to that of the first nauplius except for a small median notch appearing at the posterior margin of the body. The 1st antenna usually possesses two moderately long and one short lateral, two long and one short terminal setae. The endopod of the 2nd antenna bears two short lateral, two long and rarely one short terminal setae. The exopod bears three long lateral, two long and one short terminal setae. The furcal spine formula is still 1 + 1.

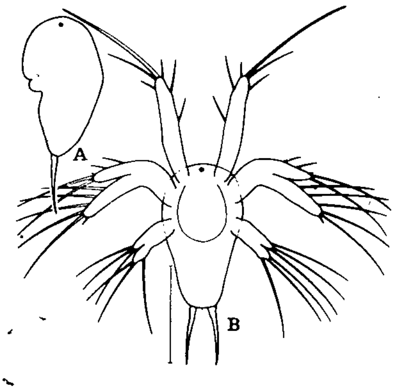

Fig. 31. Second nauplius, lateral (A) and ventral (B) views. Scale represents 0.2 mm.

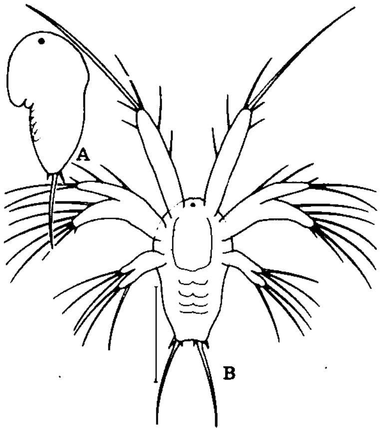

Fig. 32. Third nauplius, lateral (A) and ventral (B) views. Scale represents 0.2 mm.

Third nauplius

The 3rd nauplius measures from 0.36 to 0.42 mm in total length with an average of 0.39 mm, and from 0.19 to 0.22 mm in body width with an average of 0.20 mm (Fig. 32). The body becomes more elongated. The furcal spines increase to 3+3, 2 + 3 or rarely 2+2 by the addition of minute spines on each furcal process. The 1st antenna has two moderately long and one short lateral, and two long and one moderately long terminal setae. The endopod of the 2nd antenna has two moderately long lateral, two long and one short terminal setae. The exopod bears three long lateral, two long, one moderately long and rarely one short terminal setae.

Fourth nauplius

The 4th nauplius measures from 0.34 to 0.43 mm in total length with an average of 0.39 mm, and from 0.17 to 0.20 mm in body width with an average of 0.19 mm (Fig. 33). The body becomes slender and is elongated posteriorly. A pair of frontal sense organs are present on the anterior margin of the body.

The 1st antenna possesses two moderately long (plus rarely one short) lateral, two long and one short terminal setae. The endopod of the 2nd antenna bears two moderately long lateral, and three long terminal setae. The exopod has four long lateral, two long and one (or rarely two) short terminal setae. The furcal spines increase to 3 + 4 (or sometimes 3 + 3 or 4 + 4) by the addition of a very small inner spine on the one or both furcal processes.

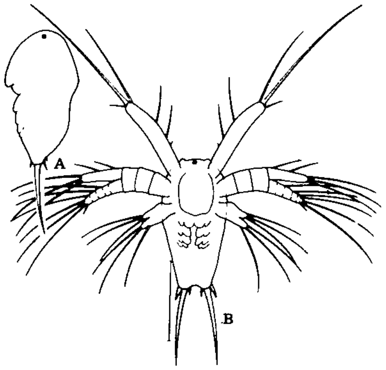

Fig. 33. Fourth nauplius, lateral (A) and ventral (B) views. Scale represents 0.2 mm.

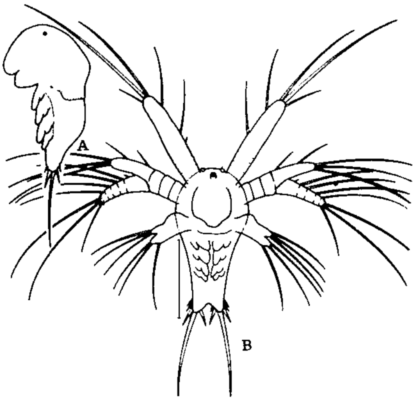

Fig. 34. Fifth nauplius, lateral (A) and ventral (B) views. Scale represents 0.2 mm.

Fifth nauplius

The 5th nauplius measures from 0.39 to 0.42 mm in total length with an average of 0.19 mm (Fig. 34). The 1st antenna possesses two long and rarely one short lateral, two long and one moderately long terminal setae. The 2nd antenna has the endopod bearing two moderately long lateral and three long (plus rarely one short) terminal setae, and the exopod bears 4 long and one short lateral, two long, one moderately long and one (sometimes absent) small terminal setae. The furcal spines increase to 5 + 6 or 5 + 5 by the addition of minute inner spines on each furcal process.

Sixth nauplius

The 6th nauplius measures from 0.50 to 0.58 mm in total length with an average of 0.54 mm, and from 0.19 to 0.21 mm in body width with an average of 0.20 mm (Fig. 35). One characteristic of this substage is the presence of rudimental carapace, which first appears in the preceding substage, becoming distinct on the body surface. The 1st antenna bears two long, two moderately long and one short lateral, and two long and one moderately long terminal setae with a slight variation. The endopod of the 2nd antenna has two moderately long and one short lateral setae, of which one of the moderately long setae is closely located to the short one at its base, and three long and one short terminal setae. The exopod has four long, one moderately long and one short lateral, and three long, one moderately long and one (sometimes lacking) small terminal setae making a total of 10 or 11 setae. Furcal development at the posterior end is more pronounced, and a pair of new spines grow inside and outside of the furca resulting in a spine formula of 7+7.

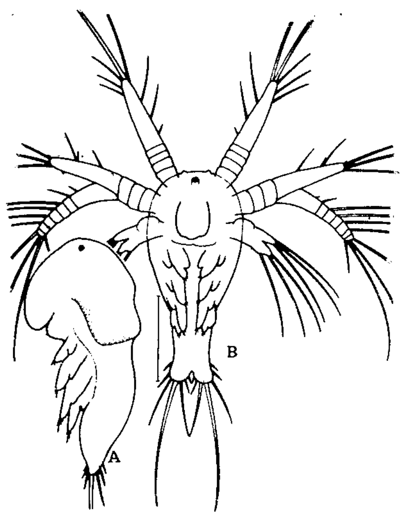

Fig. 35. Sixth nauplius, lateral (A) and ventral (B) views. Scale represents 0.2 mm.

First protozoea

Hudinaga (1942) and others used "zoea" for stages after nauplius. However, the present author wants to apply the term "protozoea" after the definition by Williamson (1969) that "The term protozoea is applicable to the first three post-naupliar stages in the Penaeidae, the carapace is developed but not fused to the thorax; the thorax is segmented from the 1st stage, the abdomen from the second; paired eyes present, although they may not be functional in the 1st stage.

The first three post-naupliar substages of a penaeid shrimp have a structure so markedly different from the rest of the larval stages. The 1st protozoea measures from 0.96 to 1.17 mm in total length with an average of 1.06 mm, from 0.47 to 0.58 mm in carapace length with an average of 0.53 mm, and from 0.39 to 0.42 mm in carapace width with an average of 0.40 mm (Fig. 36).

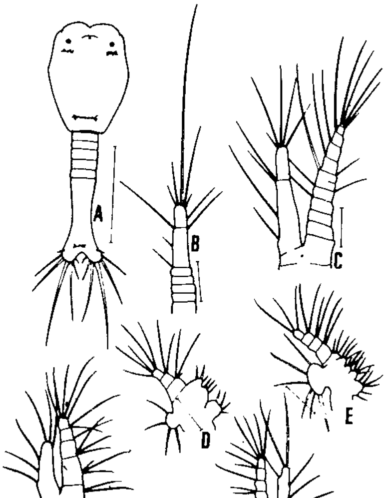

Fig. 36. First protozoea. A, dorsal view; B, first antenna; C, second antenna; D, maxilla; E, second maxilla; F, first maxilliped; G, second maxilliped. Scale for A represents 0.5 mm and others for B to G 0.1 mm.

The body is clearly divided into two parts. The anterior part is covered by a loose-fitting carapace. The narrow posterior part is divided into a six-segmented thorax and an unsegmented abdomen. The mandible is greatly enlarged, and the endopod and exopod are lost.

The maxillae and maxillipeds are large and functional. The carapace is rounded with a median notch at the anterior end. An ocellus, which persists in subsequent protozoeal substages, is present between a pair of compound eyes covered with the carapace.

The 1st antenna, which is about equal in length to the endopod plus the protopod of the 2nd antenna, is composed of three major segments. The basal segment is divided into five articulations bearing one short seta. The 2nd segment possesses three setae; one short and two long terminal setae. The distal segment has one lateral and five terminal setae.

The 2nd antenna consists of a protopod of two segments, an endopod of two segments, and an exopod of 11 segments. The endopod bears one moderately long seta near the junction with the protopod, one lateral, two terminal on the proximal, another lateral and five terminal setae, one short and four long setae on the distal segment. The exopod has eight setae on its lateral margin, in addition to five terminal setae.

This is the first feeding stage. The 1st maxilla is composed of an unsegmented protopod, an endopod of three segments, and a small knoblike exopod bearing four setae. The protopod consists of two large lobes of which the distal one is bilobed; the proximal lobe of the protopod bears four, and the distal lobe six stout toothed spines. The endopod possesses three (rarely two) setae on the 1st, two setae on the 2nd, and five setae on the distal segment.

The 2nd maxilla is about the same size as in the first. It has an unsegmented protopod, an endopod of five segments, and a knoblike exopod. The protopod has four lobes, the basal lobe bears approximately six setae, the remaining lobes three to four. The 2nd to 4th segments of the endopod have two setae, and the 1st and 5th three. The exopod has five setae.

The 1st maxilliped has a protopod of two segments, an endopod of four segments, and an unsegmented exopod. The endopod possesses three setae on the 1st and 2nd, one seta on the 3rd, and five setae on the terminal segment. The exopod has three or four lateral and three terminal setae.

The 2nd maxilliped, though smaller, is quite similar in structure to the first. The endopod is composed of four segments, the 1st and the 3rd have two, the 2nd one, and the 4th five setae. The exopod has three or four lateral and two or three terminal setae. The 3rd maxilliped is present only as a small bud.

The telson furcates with 7 + 7 spines, of which the inner second and third are located close to each other at the base and remain so throughout the protozoeal stage.

Second protozoea

The main differences between this substage and the preceding one are the presence in the 2nd protozoea of a ventrally projected rostrum and a pair of bifurcated supra-orbital spines, the appearance of stalked compound eyes free from the carapace and the segmentation of the abdomen.

The 2nd protozoea measures from 1.72 to 2.04 mm in total length with an average of 1.89 mm, from 0.70 to 0.77 mm in carapace length with an average of 0.73 mm, and from 0.54 to 0.65 mm in carapace width with an average of 0.58 mm (Fig. 37). Segmentation of the appendages remains the same as was described for the 1st protozoea. Rudiments of the 3rd maxilliped and five pairs of pereiopods are present. The abdomen is divided into six segments, the telson not separated from the 6th. The number of furcal spines remains constant at seven pairs having the same position as those in the preceding substage.

Third protozoea

The 3rd protozoea measures from 2.97 to 3.30 mm in total length with an average of 3.12 mm, from 1.14 to 1.21 mm in carapace length with an average of 1.17 mm, and from 0.62 to 0.67 mm in carapace width with an average of 0.64 mm (Fig. 38). The major differences between this and the preceding substage are the appearance of a pair of biramous uropods and spines on the abdominal somites, aside from increase in the body size. The carapace is closely fitted and partially covers the first five thoracic somites. The supra-orbital spines are no longer bifurcated.

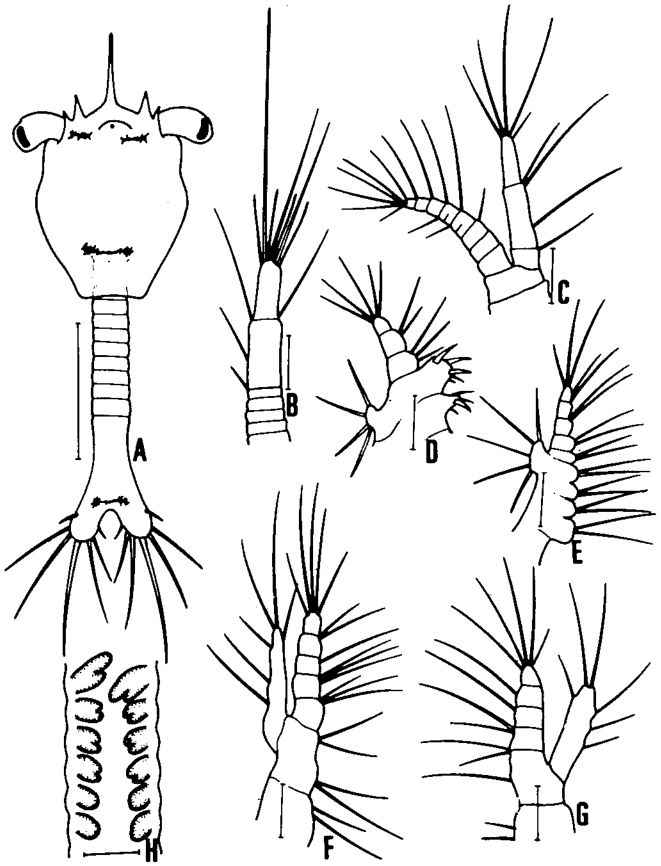

Fig. 37. Second protozoea. A, dorsal view; B, first antenna; C, second antenna; D, first maxilla; E, second maxilla; F, first maxilliped; G, second maxilliped; H, buds of third maxilliped to fifth pereiopod from upper to lower. Scale for A represents 0.5 mm, and others for B to H 0.1 mm.

The basal segment of the 1st antenna is no longer subdivided. The lateral seta originating from the middle of the second segment is lost. The 2nd antenna, mandible and maxilla remain essentially the same as in the preceding substage. Two or three setae have been added to the exopod of the 1st maxilliped. The 1st to 3rd segments of the endopod and the exopod of the 2nd maxilliped have gained one or two setae. The 3rd maxilliped and five pereiopods have developed further and are now biramous, though not yet functional.

The abdomen is of six segments plus telson. The 6th abdominal segment is about three-fourths or four-fifths the length of the preceding five segments combined. Each of the first five segments has a dorso-median spine on its posterior margin. In addition, the 5th somite has a pair of mid-lateral and a pair of ventro-lateral spines.

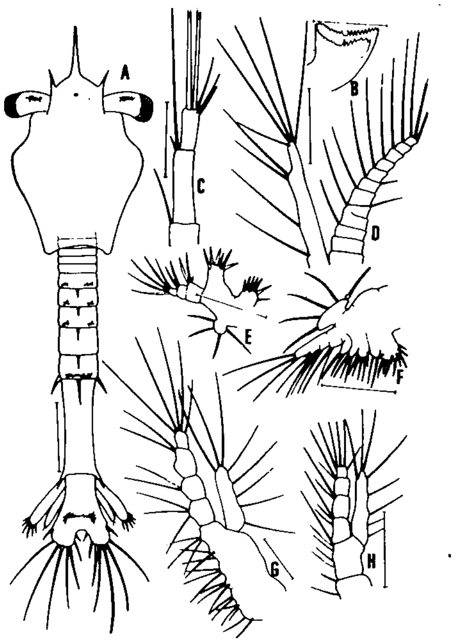

Fig. 38. Third protozoea. A, dorsal view; B, mandible; C, first antenna; D, second antenna; E, first maxilla; F, second maxilla; G, first maxilliped; H, second maxilliped. Scale for A represents 0.4 mm, for B to F and H 0.2 mm and for G 0.1 mm.

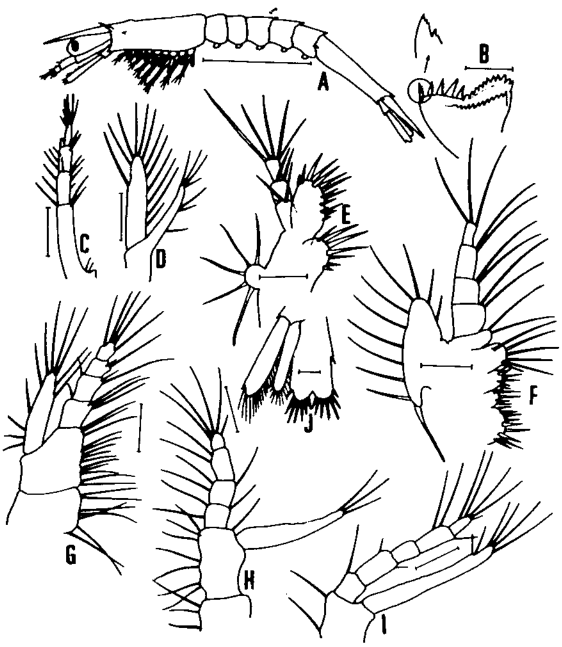

Fig. 39. First mysis. A, lateral view; B, mandible; C, first antenna; D, second antenna; E, first maxilla; F, second maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped; J, telson and uropod. Scale for A represents 1 mm, for B, E and F 0.1 mm, for C and D 0.5 mm, and for G to I 0.25 mm.

A pair of biramous uropods are present, originating from the ventro-posterior edge of the 6th abdominal segment. The exopod, slightly longer than the endopod, bears six setae around its apex, while the endopod has only two setae or is bare. An additional pair of caudal spines has been added medially on the telson, making a total of eight pairs.

First mysis

The second metamorphosis occurs when the 3rd protozoea molts into the 1st mysis stage. Specimens in this substage measure from 3.28 to 4.13 mm in total length with an average of 3.78 mm, from 1.25 to 1.41 mm in carapace length with an average of 1.31 mm, and from 0.59 to 0.68 mm in carapace width with an average of 0.63 mm (Fig. 39). The most apparent change is the development of functional exopods on the five pairs of pereiopods. The antennae also undergo considerable change, with the exopods of the 2nd antennae being modified into flattened antennal blades. The carapace fits the body more closely than in the preceding stage and covers all the thoracic somites. The rostrum is straight and protrudes forward on a horizontal plane. A small spine is present on the antero-ventral corners of the carapace. There is a small dorsal protuberance at about one-third of the distance from the anterior end of the carapace. The protuberance is retained in subsequent mysis substages. In addition, there is a pair of hepatic spines on the carapace. An ocellus is still present in this and subsequent mysis substages. The protopod of the 1st antenna is composed of three segments, the first being about one and a half times as long as the second and the third combined. The distal segment gives rise two unsegmented branches, the external one bearing six or seven setae and being twice as long as the internal one which bears no terminal seta.

The 2nd antenna consists of a protopod of two segments, an unsegmented endopod with two or three lateral and three or four terminal setae, and a flattened, unsegmented, bladelike exopod with a single outer seta and 11 setae along the inner and terminal margins. The mandible and maxilla remain essentially the same as in the preceding substage except that the exopod of the 2nd maxilla has become enlarged and bears 10 or 11 setae.

The 1st and 2nd segments of the endopod of the 1st and 2nd maxillipeds have each acquired an additional seta. The 3rd maxilliped has developed further and is almost as long as the first two. It has a two-segmented protopod bearing two setae, a five-segmented endopod with a setal arrangement of 1+2+0+3+5 from the proximal to distal with a slight variation, and an unsegmented exopod having two sub-terminal and four terminal setae.

The five pairs of pereiopods have undergone considerable enlargement and their exopods serve as the principal swimming organs during the mysis stage. The endopods of the first three pairs are modified into rudimentary chelae that have four or five terminal setae. The 1st pereiopod consists of a protopod of two segments, an unsegmented endopod, and an exopod which bears five or six terminal and sub-terminal setae.

The dorso-median spines of the first two abdominal segments have been lost while those in the 3rd, 4th and 5th segments are still prominent. The 5th segment retains a pair of mid-lateral spines. A dorso-median and a ventro-median spines are present on the 6th segment in addition to the paired mid-lateral and ventro-lateral spines. The uropod has developed an unsegmented protopod that possesses a large postero-ventral spine and a smaller postero-lateral spine. The endopod carries about 16 setae on its medial and terminal borders, while the exopod has about 18 setae on its medial and terminal margins and a prominent spine on its postero-lateral edge. The telson is cleft behind and bears seven pairs of terminal and a pair of lateral spines.

Second mysis

Specimens of the 2nd mysis measure from 4.00 to 4.69 mm in total length with an average of 4.28 mm, from 1.33 to 1.40 mm in carapace length with an average of 1.37 mm, and from 0.57 to 0.61 mm in carapace width with an average of 0.60 mm (Fig. 40). The distinguishing characteristics of this substage from the first are the development of unsegmented pleopods and a spine on the antennal blade.

The appearance of the rostrum is the same as in the preceding substage. The terminal branches of the 1st antenna are subequal in length with each other. Setation on the endopod of the 2nd antenna has been reduced to one or two (rarely three) terminal setae. The number of setae on the exopod has increased to around

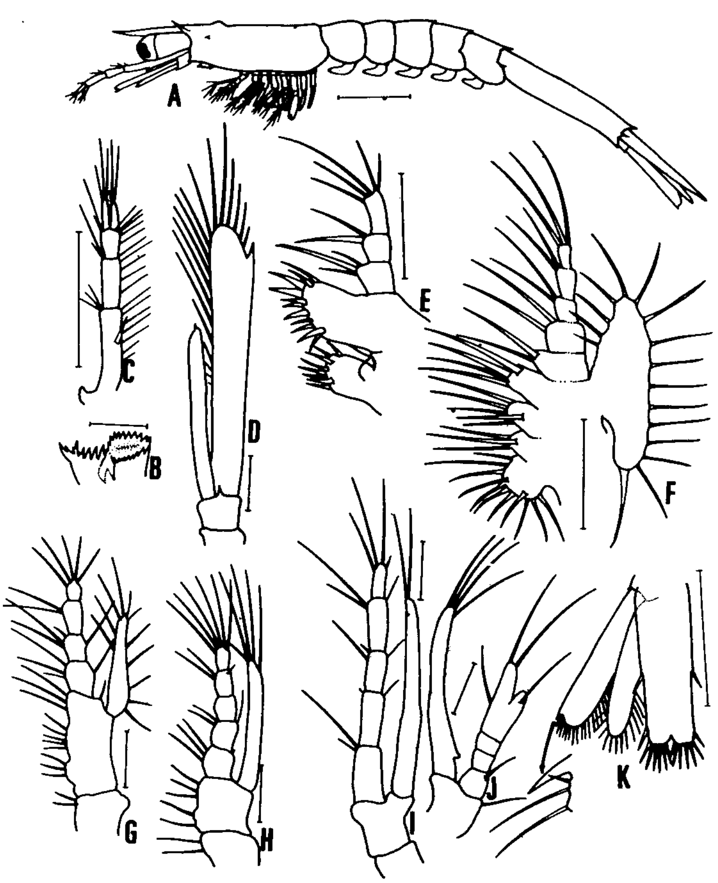

Fig. 40. Second mysis. A, lateral view; B, mandible; C, first antenna; D, second antenna; E, first maxilla; F, second maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped; J, third pereiopod; K, telson and uropod. Scales for A, C, and K represent 0.5 mm, for B and D to J 0.1 mm.

17 and they occur along the medial border and around the tip to the point of insertation of sub-terminal spine on the lateral margin. A spine has been added to the terminus of the protopod. The mandible has developed a small unsegmented palp.

The exopod of the 1st maxilla is no longer present, that of the 2nd maxilla has increased in size and now bears 13 to 16 setae including a large one.

A seta now arises from the protopod of the 1st maxilliped at a point between the insertation of the endopod and exopod. The endopod of the 2nd maxilliped is of five segments with a setal arrangement of 4+3+0+3+6 from the proximal to distal, though there is a slight variation between individuals. The protopod of the 3rd maxilliped and 1st pereiopod have each gained a seta.

The armature of the abdomen and uropods is unchanged from the preceding substage. Rudimentary, unjoined pleopods are present on the ventral surface of the first five abdominal segments. The telson has six pairs of terminal and two pairs of lateral spines.

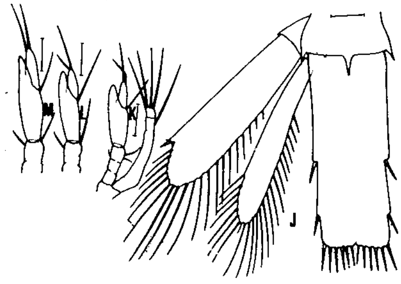

Fig. 41. Third mysis. J, telson and uropod; K, first pereiopod; L, second pereiopod; M, third pereiopod. Scale represents 0.1 mm.

Third mysis

Individuals of the 3rd mysis measure from 4.05 to 4.87 mm in total length with an average of 4.56 mm, from 1.35 to 1.53 mm in carapace length with an average of 1.46 mm, and from 0.58 to 0.69 mm in carapace width with an average of 0.63 mm (Figs. 41 and 42). The distinguishing characteristics of the 3rd mysis are the appearance of a dorsal spine (sometimes lacking) on the rostrum and of well-developed pleopods. In addition, the pleopods and endopod of the 2nd antenna are composed of two segments. The armature of the carapace remains essentially the same as in the second mysis.

The outer branch arising from the distal segment of the 1st antenna is longer than the inner branch and is sometimes composed of two segments. A lateral seta has been added to the endopod of the 2nd antenna which is now also composed of two segments. The mandibular palp is slightly longer than in the preceding stage and sometimes has a weak apical seta.

The 1st maxilla and 1st maxilliped remain unchanged. The exopod of the 2nd maxilla has become elongated and has 17 to 20 setae, while those of the 2nd and 3rd maxillipeds and 1st pereiopods have two segments. The 3rd and 4th segments of the endopod of the 2nd maxilliped have gained one seta as has the exopod. One seta has been added to the 1st, 3rd and 4th segments of the endopod of the 3rd maxilliped with a slight variation. The endopod of the pereiopods is composed of five segments with the terminal two forming the chela, the 2nd segment has gained one seta, and the 3rd, two. The pleopods are now composed of propodus and ramous and bear two to four terminal setae.

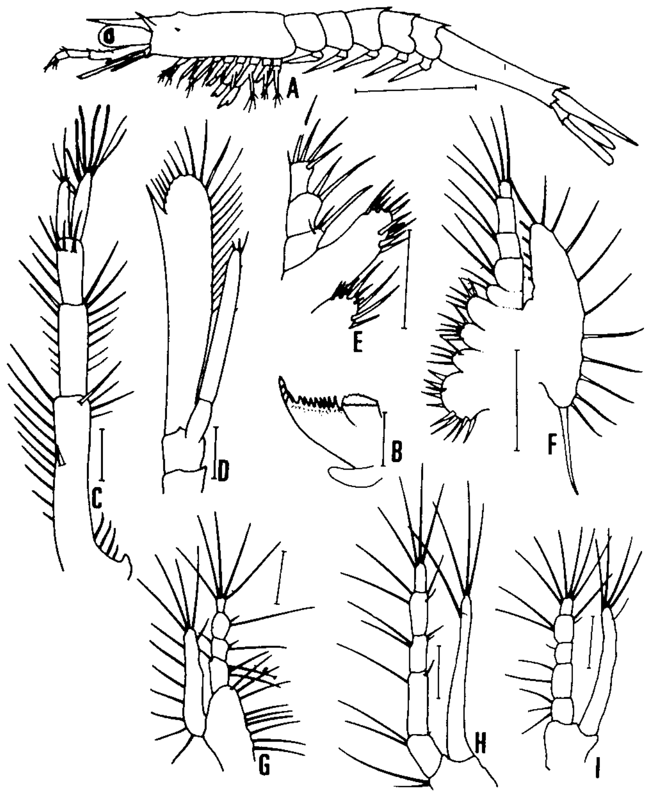

Fig. 42. Third mysis. A, lateral view; B, mandible; C, first antenna; D, second antenna; E, first maxilla; F, second maxilla; G, first maxilliped; H, third maxilliped; I second maxilliped. Scales for A to F represent 0.1 mm and for G to I 0.25 mm.

VIII-3 Megalopa and juvenile

According to Kurata and Pusadee (1974), the term "megalopa" has not usually been recognized in larval development of penaeid prawns, and the immediate stage after the mysis is commonly known as the first postlarva. It is well known, however, that the so called postlarvae of the first few stages are planktonic and show pelagic rather than benthic habits, according to Pearson (1939) and Hudinaga (1942). The equivalent phase in other decapod crustaceans is very distinct in morphology and behavior, and has special names, *puerulus* in Palinurid lobster, *glaucothoe* in Anomura and *megalopa* in Brachyura (Kurata and Pusadee, 1974). These stages are regarded as a larva rather than adult by Williamson (1969).

Table 2. Comparison of the larval characters of *P. monodon* and *P. japonicus*.

Characters	**Stage**	*P. monodon* **(present author)**	*P. japonicus* **(Hudinaga, 1942)**
Number of setae on first antenna	Nauplius I-III	6	7
	IV-V	5 or 6	7
Number of setae at tip of endopod of second antenna	Nauplius VI	4	5
Setation on endopod of first maxilliped*	Protozoea I	2(or 3) +1+2+5	3+2+2+5
	Mysis I-III	4+3+2+5	3+2+2+5
Setation on endopod of second maxilliped*	Protozoea I	2+1+2+5	1+1+1+5
Number of setae on exopod of second maxilla	Protozoea III	5	6
Number of segments in endopod of second maxilliped*	Mysis II	5	4
Setation on endopod of third maxilliped	Mysis III	3+2+4 (or 3) +4+5	1+2+3+4+6

*Setation is arranged from proximal to distal segment.

Kurata and Pusadee (1974) suggested the name "megalopa" instead of "postlarva", after Williamson (1969). The present author would like to adopt this nomenclature.

Table 3. Abbreviations used in illustrations.

Ab	Arthrobranchia	Mr	Merus
As	Antennal spine	O	Otolith
Bs	Basis	Of	Outer flagellum
Cr	Carpus	Pa	Palp
Cx	Coxa	Pb	Podobranchia
Dt	Dactylus	Plb	Pleurobranchia
Enp	Endopod	Pp	Propodus
Es	Epigastric spine	Pr	Protopod
Exp	Exopod	Pt	Prosartema
Hs	Hepatic spine	Sc	Scaphocerite
Ich	Ischium	Sg	Scaphognathite
If	Inner flagellum	St	Stylocerite
Mb	Mastigobranchia		

The term "postmysis" is collectively used in the present study to denote those stages following mysis even if there is no major morphological distinction from subsequent juvenile stage.

The objectives are to show the morphological development of the postmysis stage and to define the megalopa and juvenile stages of the giant tiger prawn.

Rostrum and carapace (Fig. 43)

In the 1st postmysis substage, the rostrum is straight and exceeds tip of eye, and has one dorsal and no ventral spine. At every molt, the rostrum becomes longer, and the number of dorsal spines increases and a ventral spine first appears at the 5th or 6th substage. The complete rostral spine formula, viz. 7 dorsal and 3 ventral is not attained until the 7th or 8th substage. In the 1st substage, supra-orbital, pterygostomian and antennal spines are absent unlike those of the first two mysis substages, although some specimens belonging to the 1st substage have a rudimental supra-orbital spine. By the 7th substage, the antennal spine begins to appear. A hepatic spine is present from the 1st substage and develops further with each molt. The development of the rostral spines and mean carapace length are shown in Table 4.

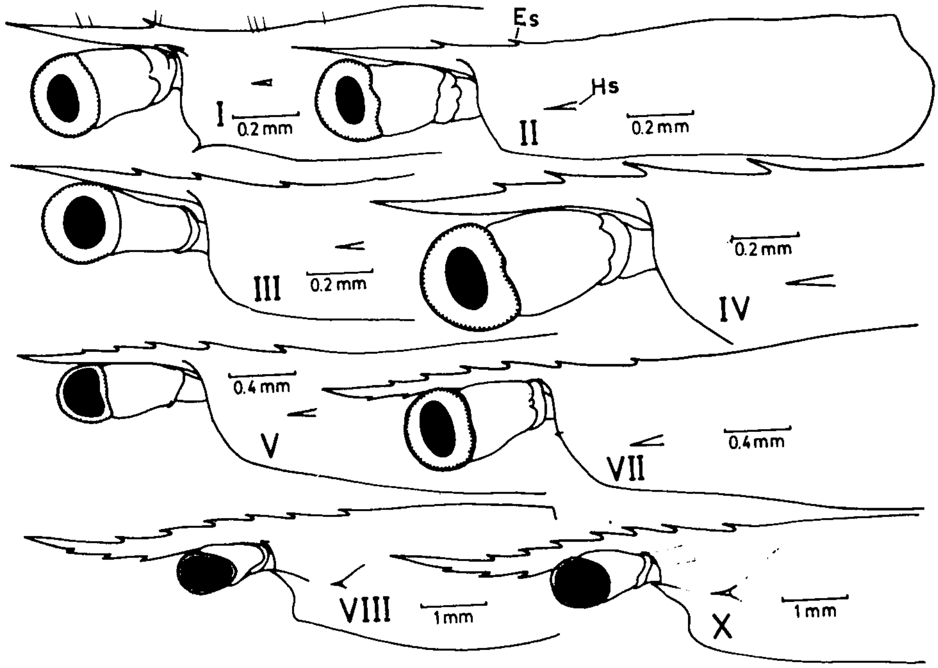

Fig. 43. Development of carapace and rostrum in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

Table 4. Rostral spine formula and mean carapace length (CL) of the postmysis*P. monodon.*

Substage	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Dorsal spine*	1	2	3	4	4-5	5-6	6-7	6-7	7	7	7	7
Ventral spine	0	0	0	0	0-1	1-2	2-3	2-3	3	3	3	3
CL (mm)	1.3	1.5	1.8	2.1	2.5	3.1	3.7	4.4	5.1	5.7	6.3	7.0

*Including epigastric spine when present.

Telson and uropod (Fig. 44)

Since the 2nd substage, the telson is furnished with plumose hairs of which the number increases with development.

In the 1st substage, the telson is almost rectangular or slightly broader posteriorly with 2 pairs of lateral, 1 pair of sublateral and 5 pairs of terminal spines. The outermost pair of terminal spine is the largest and stoutest. The hind margin of the telson is observed to have a shallow notch in the center.

By the 2nd substage, the paired sublateral spines in the previous substage have moved upward becoming completely lateral. The posterior margin has no notch and shows a more or less straight or slightly convex profile. At the 3rd substage the telson becomes slender posteriorly, the lined margin appears as a convex line, although other remarkable morphological changes are not found.

By the 4th substage, the telson becomes more slender posteriorly and 3 pairs of lateral spines are observed far from the posterior margin. The terminal margin becomes prominently convex.

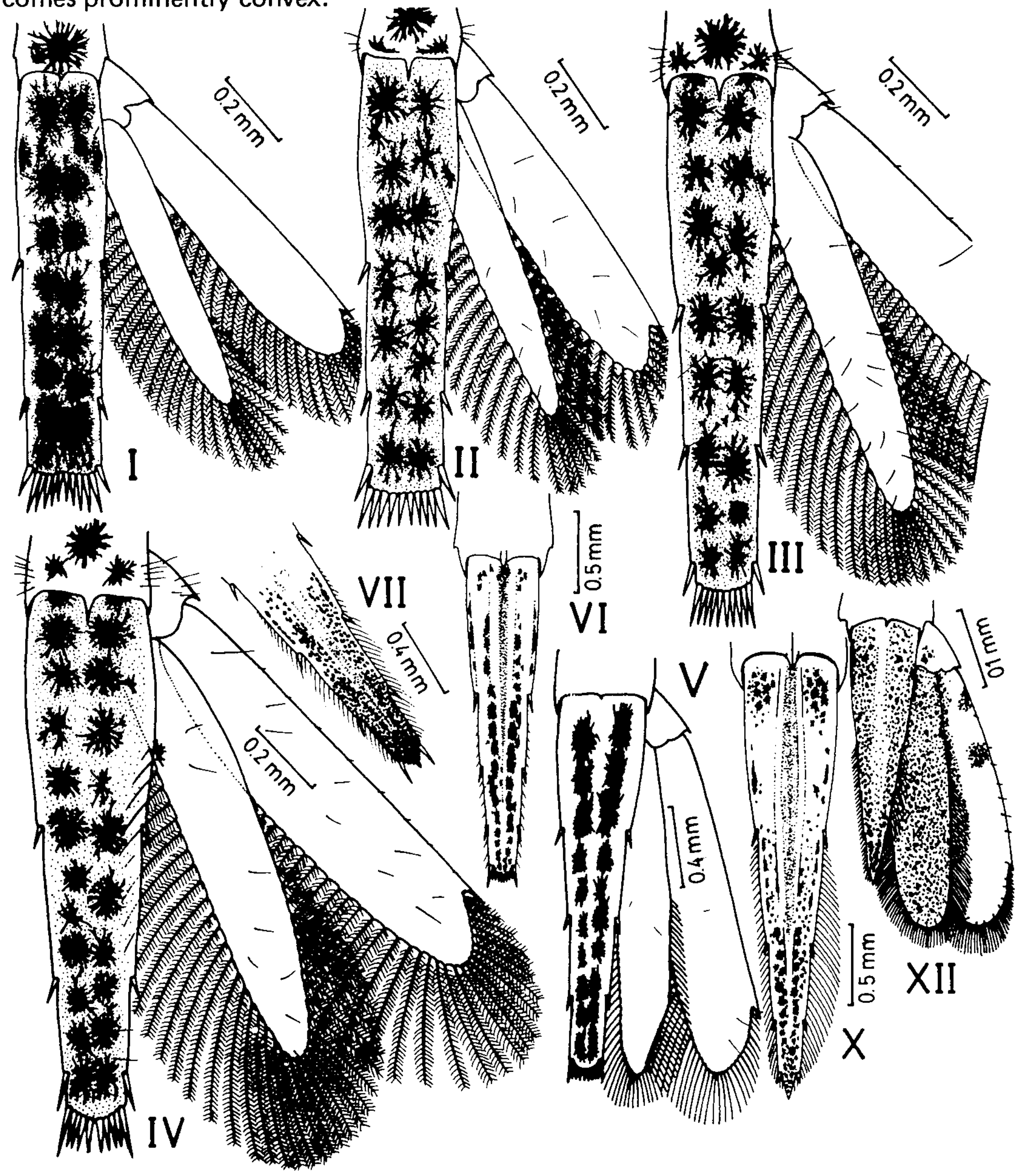

Fig. 44. Development of telson and uropods in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

By the 6th or 7th substage, the terminal margin becomes acutely convex and at its center one robust process is present resulting in a cuneiform appearance. The paired outermost spines are the most prominent and longest.

The telson spine formula for the respective substages as shown in Table 5, is observed to be 8+8 from the 1st to the 7th substages. From the 8th substage onwards, however, the number of the spines is found to decrease with each molt.

By the 9th substage, the telson becomes sharply pointed posteriorly with 4 lateral spines, and one of the paired inner terminal spines disappears.

The uropods are slightly shorter than the telson during the 1st and 6th substages, and after this they are longer than the latter.

Table 5. Telson spine formula of postmysis *P. monodon*.

Substage	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Spine Formula	8+8	8+8	8+8	8+8	8+8	8+8	8+8	7+7	5+5	4+4	4+4	4+4

First antenna (Fig. 45)

The 1st segment of the peduncle is longer than the other two, being at least twice the length of the 2nd.

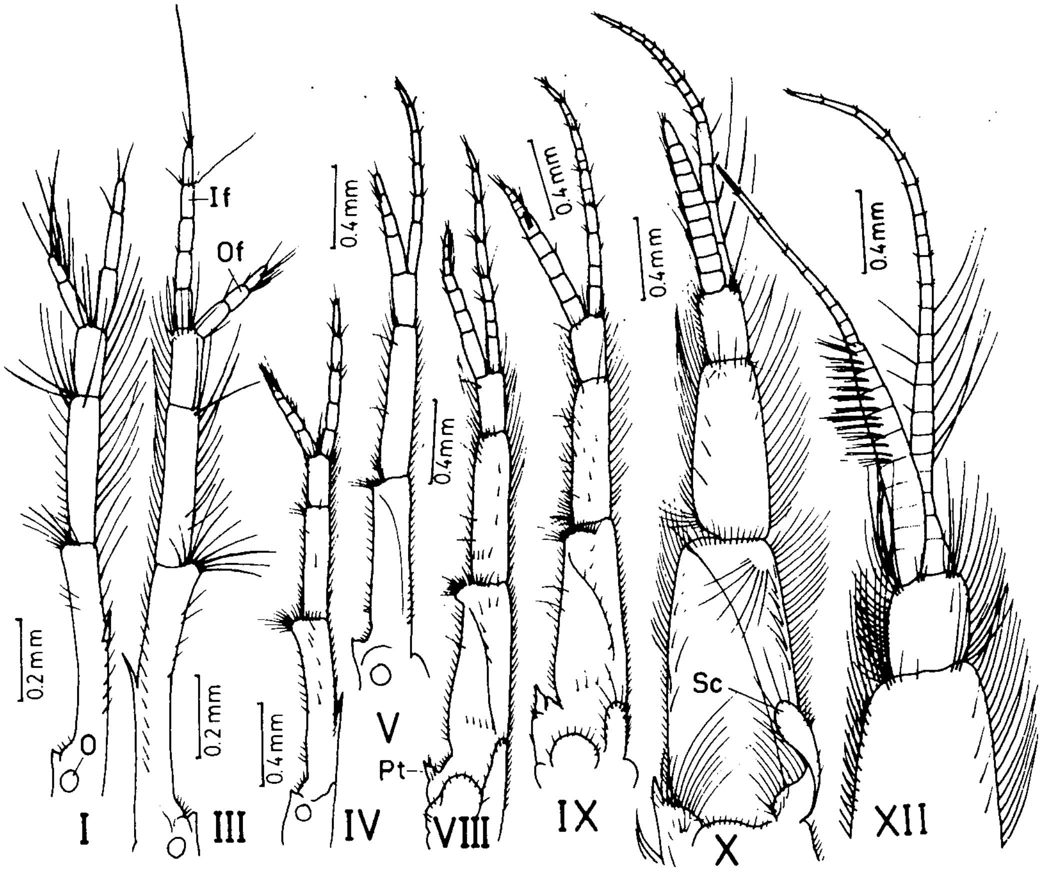

Fig. 45. Development of first antenna in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

At the 1st and 2nd substages, the inner (lower) and outer (upper) flagella of the 1st antenna consist of 3 and 2 segments respectively, of which the former is about 1.9 times as long as the latter (excluding hairs). During the 3rd to 6th postmysis, this ratio increases to as much as 2.3, but decreases during later substages, and finally becomes almost constant 1.0. The number of the segments is observed to increase with eacn molt. However, the peduncle has consistently 3 segments, furnished with an otolith (statocyst) at the base of the 1st segment, since the 1st substage. In the 8th or 9th substage a prosartema growing on its inner side gradually lengthens. The number of segment of antennular flagella and their relative length, both increase with every molt (Table 6), although the numbers vary particularly in later substages.

Table 6. Number of antennular segment and the length ratio of postmysis *P. monodon*.

Substage	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Inner	3	3	5-6	6-6	6	6-7	6-7	7-8	11-12	14	18	21
Outer	2	2	3	3-4	4	4-5	5	7	8-9	10	14	20
Length ratio (inner/outer)	1.9	1.9	2.3	2.2	2.1	2.0	1.8	1.6	1.4	1.2	1.1	1.0

Second antenna (Fig. 46)

In the 1st substage, the endopod which consists of 5 or 6 segments is about 0.7 times the length of exopod (scaphocerite) which is broader distally having about 28 plumose hairs along its periphery.

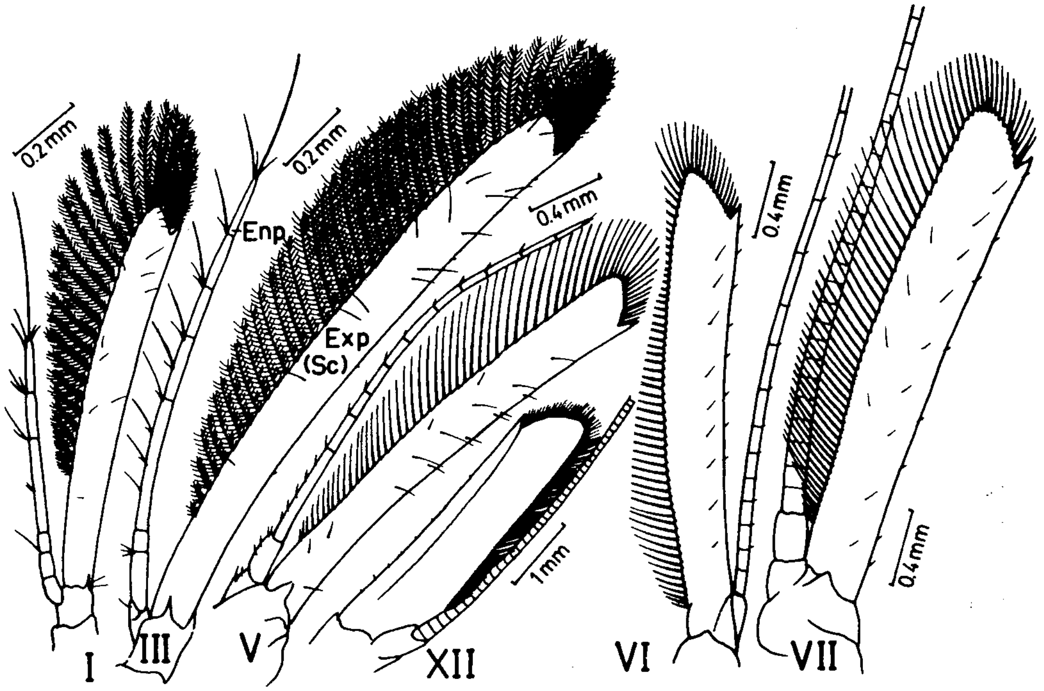

Fig. 46. Development of second antenna in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

By the 3rd substage, the endopod has 8 or 9 segments and is elongated though still shorter than the exopod. Until the 6th substage, the exopod is broader distally, and at the 7th it is almost parallel sided and thereafter it becomes broader proximally. The endopod grows rapidly with every molt and by the 6th or 7th substage it has become longer than the exopod, and consists of more than 40 segments. By the 8th substage, the endopod is almost 2.6 times the exopod in length, having about 50 segments.

Mandible (Fig. 47)

In the 1st substage, the number of teeth on the cutting edge and molar process decreases, although they become sharper, compared with those in the mysis stage. The palp consists of 2 segments with several setae, although in some cases, segmen-

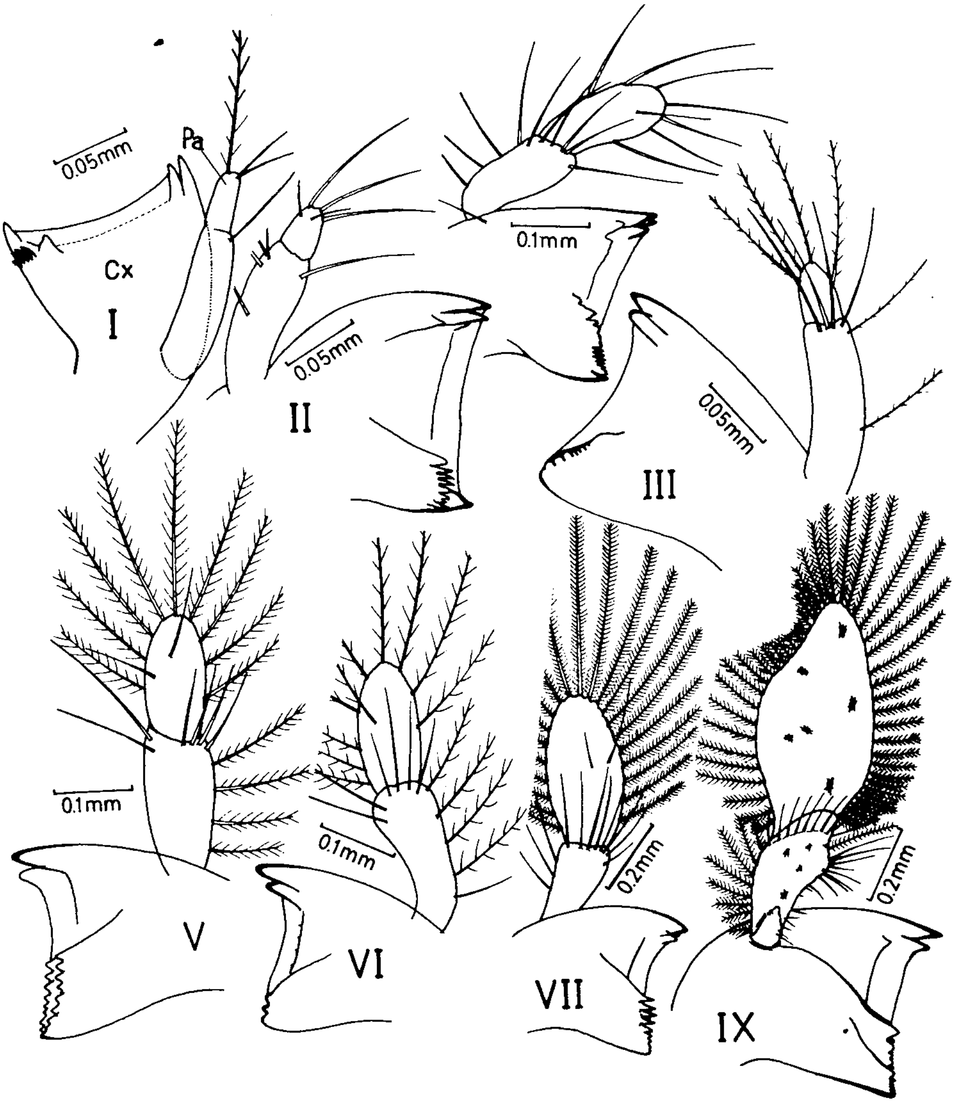

Fig. 47. Development of mandible in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

tation is not clear. By the 3rd substage, the molar process has lost most of its teeth and becomes flat and smooth leaving a few strong sharp teeth. The number of teeth on the cutting edge eventually becomes 2 or 3. The palp grows with every molt and the number of plumose hairs on the periphery increases. The distal segment of the palp becomes transformed morphologically from a rod-shape to an oval-shape by the 4th or 5th substage, while increasing in size.

By the 9th substage, the distal segment becomes more or less pear-shaped having greatly increased in size and in the number of the plumose hairs at the periphery.

First maxilla (Fig. 48)

The 1st maxilla is made up of coxa, basis and endopod. In the 1st substage, the basis has about 10 setae, while the coxa has less than 10 and is always smaller than the basis. The endopod consists of 3 segments with 2 (or 3), 2 and 3 (or 4) plumose spines respectively from the proximal to the distal, and from the 2nd substage, the segmentation of the endopod disappears. By the 5th substage there are 3 spines on the inner side of the basis, and thereafter the number increases at almost every molt. As the postmysis grows, the endopod gets smaller and the number of spines decreases until the 7th substage. However, in the 8th, it becomes larger and shows an increase in the number of spines.

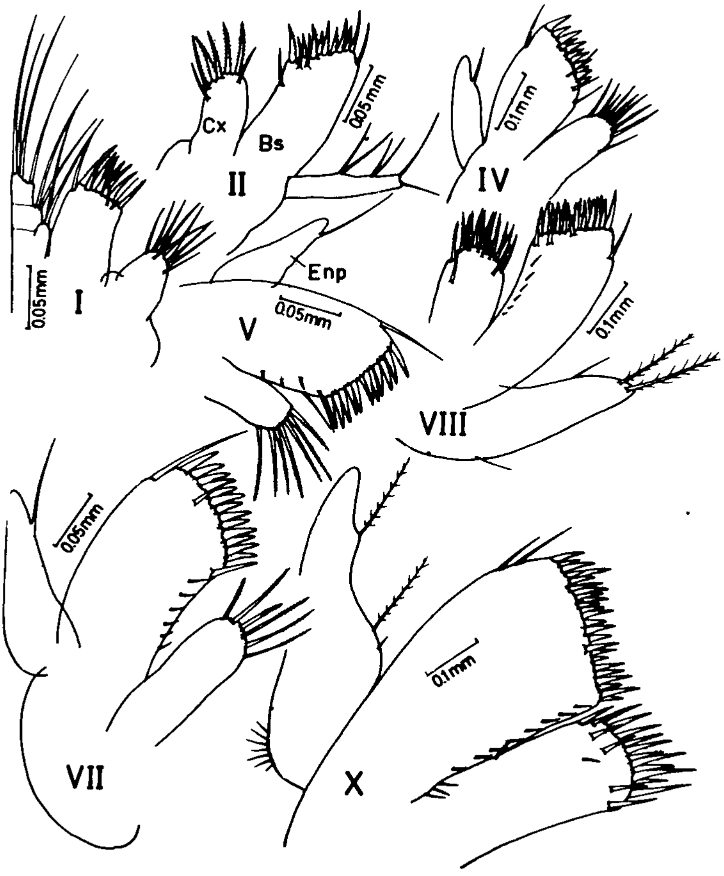

Fig. 48. Development of first maxilla in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

Second maxilla (Fig. 49)

The 2nd maxilla is consisted of coxa, basis, endopod and scaphognathite. In the 1st substage, the coxa has 2 lobes and the basis 2, and the proximal lobe of the coxa is largest followed by that of the basis. Between the basis and endopod there is a small lobe with 2 hairs but this disappears in the later substages. This may be the 1st segment of the endopod. The endopod consists of 3 segments, with a setation formula of 1 + 1 + 2 from the proximal to the distal portion with a slight variation in the 1st substage. However, this degenerates with each successive molt. The well developed scaphognathite is larger than that in the 3rd mysis, and has about 26 plumose hairs on its periphery in the 1st substage. After the 5th substage, it becomes the main part of the 2nd maxilla subordinating the other parts. During the 2nd and further substages, 2 lobes of the coxa become smaller, while the remaining lobes and the basis are relatively more developed. At the 4th or 5th substage, the endopod has 3 small teeth, and subsequently the number increases at every molt.

The scaphognathite continues to develop with each molt, becoming larger, and the number of plumose setae at its periphery also increases.

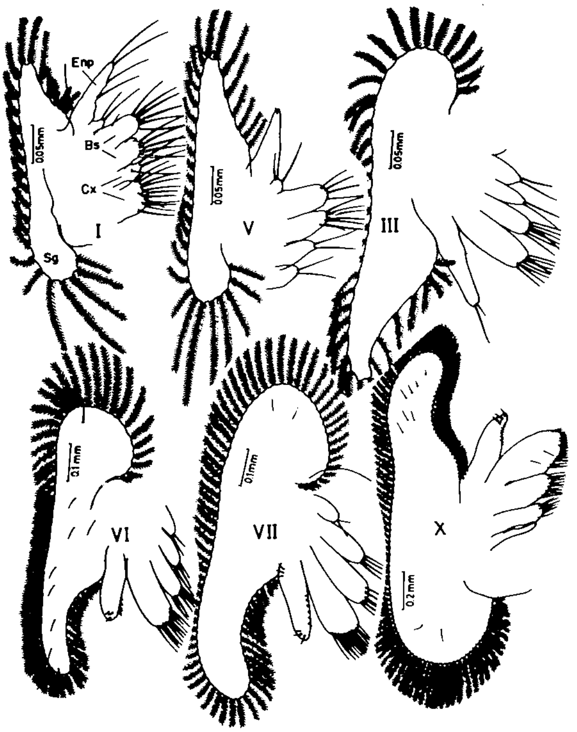

Fig. 49. Development of second maxilla in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

First maxilliped (Fig. 50)

The 1st maxilliped consists of a three-lobed coxa, a basis with 1 or 2 lobes, an endopod made up of 4 segments and an exopod, each has several plumose hairs in the 1st substage. The endopod, now degenerated, has a setation formula of 3+1+1+3 from the proximal to the distal and with a slight variation at the 1st substage. The exopod which is also markedly degenerated has several plumose hairs at its tip and periphery.

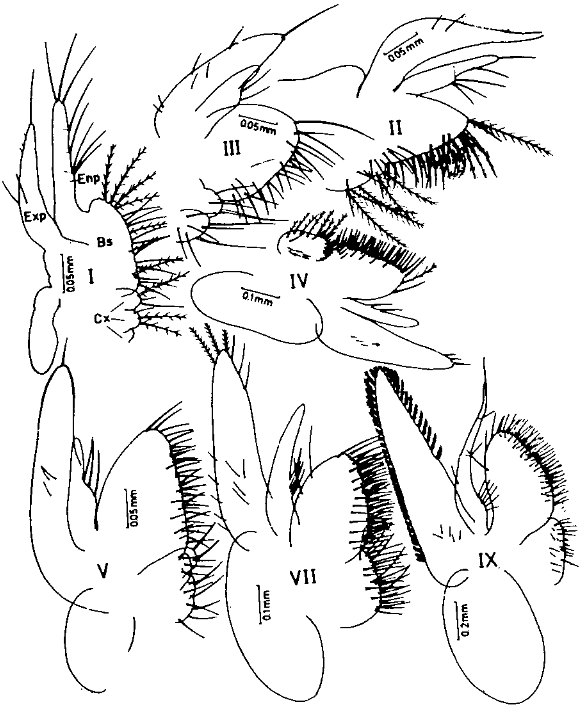

Fig. 50. Development of first maxilliped in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

In the 2nd substage, the endopod is further reduced in size and the number of segments falls to 1 or 2. The exopod has fewer plumose hairs, although it becomes larger. By the 4th substage, the endopod has become greatly degenerated, although 2 or 3 strong sharp spines are present at the periphery. The exopod is smaller than the endopod and the number of plumose hairs remains 2 or 3 at its tip. Setae are present on the mastigobranchia for the first time after molting into the 10th substage, their number increasing in the later substages. From the 7th substage onwards, however, the endopod redevelops and becomes longer and narrower. In the 9th substage, the slightly curved endopod is made of 3 joints.

Second maxilliped (Fig. 51)

The 2nd maxilliped consists of a protopod, an endopod and an exopod. In the 1st substage, the coxa of protopod has 2 or 3 setae and the basis about 6. The well developed endopod consists of 5 segments, of which the second is longest, and the 3 distal segments becoming concave in later substages. The exopod has 4 plumose hairs at its tips. The mastigobranchia present from the 1st substage and the podobranchia present from the 2nd substage are both morphologically primitive.

In the 2nd substage, the exopod is less than one-half the length of the endopod, becomes degenerated, and is devoid of hairs. In the 3rd substage, the exopod is rudimentary, while the podobranchia is more developed. At the 4th or 5th substage, the exopod reappears. It has 4 terminal hairs, and the podobranchia is well developed and by the 7th substage it is foliated. In the 8th or 9th substage, the exopod exhibits tremendous development having about 20 plumose hairs at its tip and periphery, and by the 10th substage its length exceeds that of endopod. The podobranchia develops likewise by the 10th substage. A further arthrobranchia appears at the 7th or 8th substage.

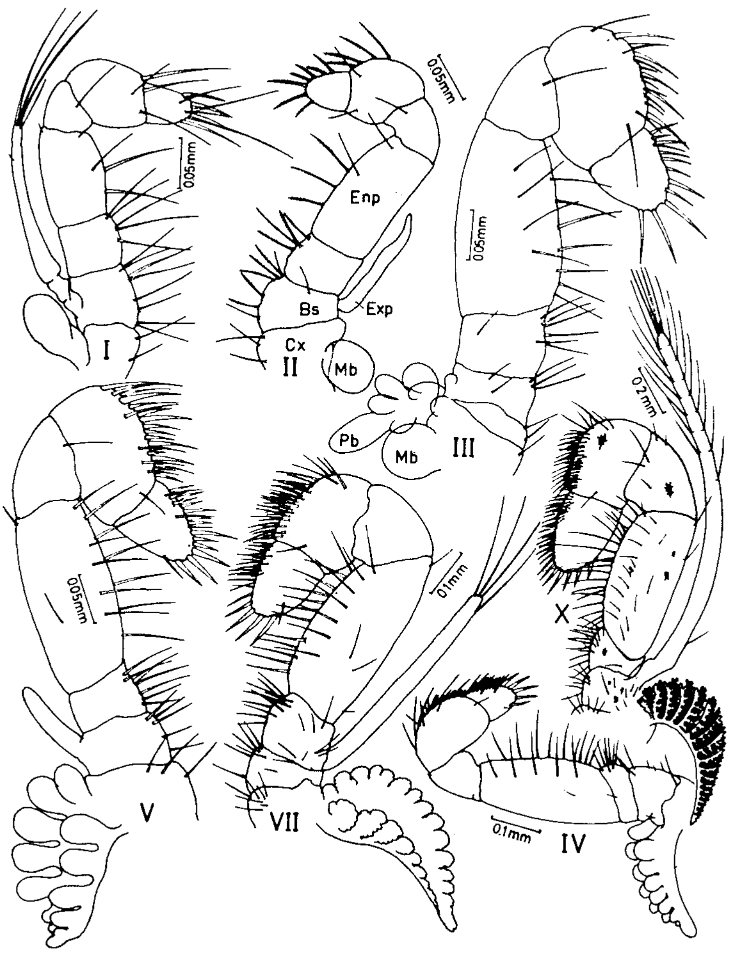

Fig. 51. Development of second maxilliped in postmysis *P. monodon.* Roman numerals denote substage of postmysis.

Third maxilliped (Fig. 52)

Among the 3 pairs of the maxillipeds, the 3rd undergoes the least changes. The endopod consists of 5 segments; ischium, merus, carpus, propodus and dactylus, of which the merus is longest. The exopod extending from the basis has 4 or 5 plumose hairs at its tip in the 1st substage and becomes degenerated in the successive substages. However, by the 8th or 9th substage, it has regenerated and continues to grow during the later substages. In the 11th the exopod shows great development with about 7 hairs at its tip. The arthrobranchia present from the 1st substage becomes foliate in the 5th substage. A podobranchia appears in the 3rd substage.

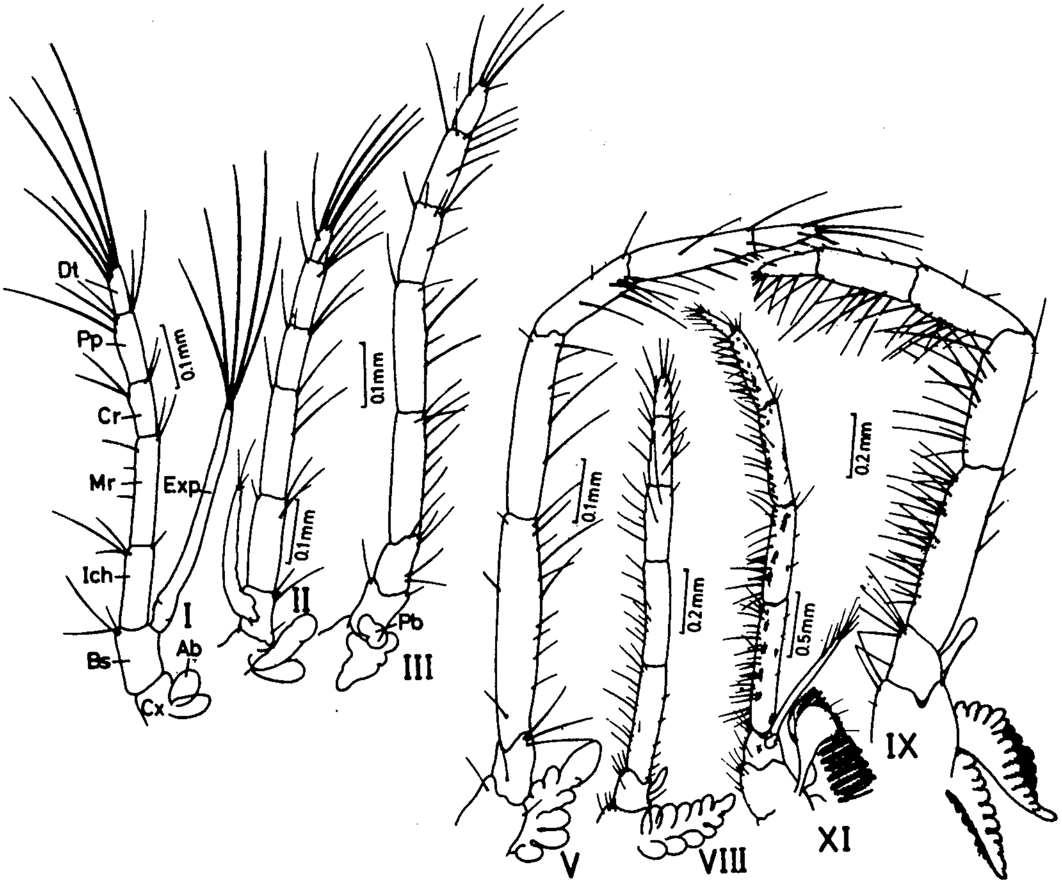

Fig. 52. Development of third maxilliped in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

First, second and third pereiopods (Fig. 53)

The 1st, 2nd and 3rd pereiopods are chelated, same as in other penaeids. The pincer is formed by an immovable propodus and movable dactylus fingers.

In the 1st substage, the exopod is two-thirds as long as the endopod in the 1st cheliped, one-half as long as endopod in the 2nd cheliped, and one-third as long as endopod in the 3rd cheliped, and each has 4 or 5 setae at its tip. From the 1st substage paired arthrobranchiae are distinct, and are more or less foliate by the 4th substage. Pleurobranchiae are present from the 4th substage and are foliate.

The 3 pairs of chelipeds are morphologically very similar but exhibit a decrease in size from the 3rd to the 1st. The development of the 3rd pereiopod is shown in Fig. 53.

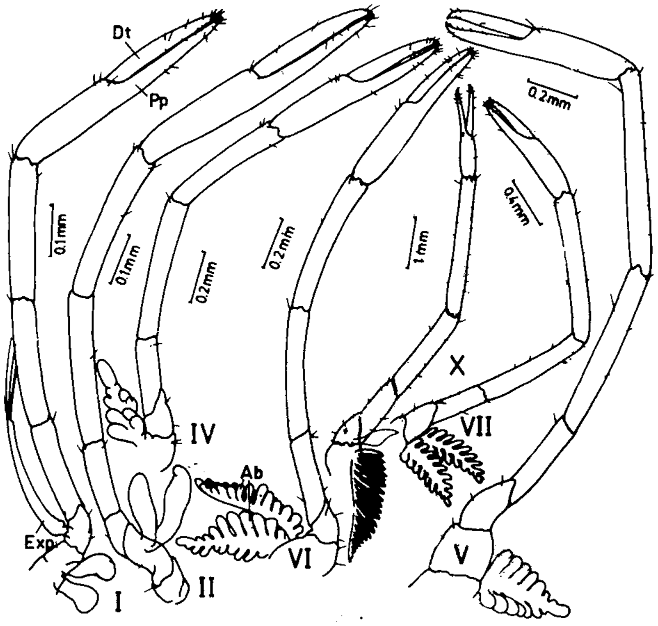

Fig. 53. Development of third pereiopod in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

Fourth and fifth pereiopods (Fig. 54)

Both the 4th and 5th pereiopods are morphologically similar to each other, although the 5th is slightly longer than the 4th. The distal 2 segments of both pereio-

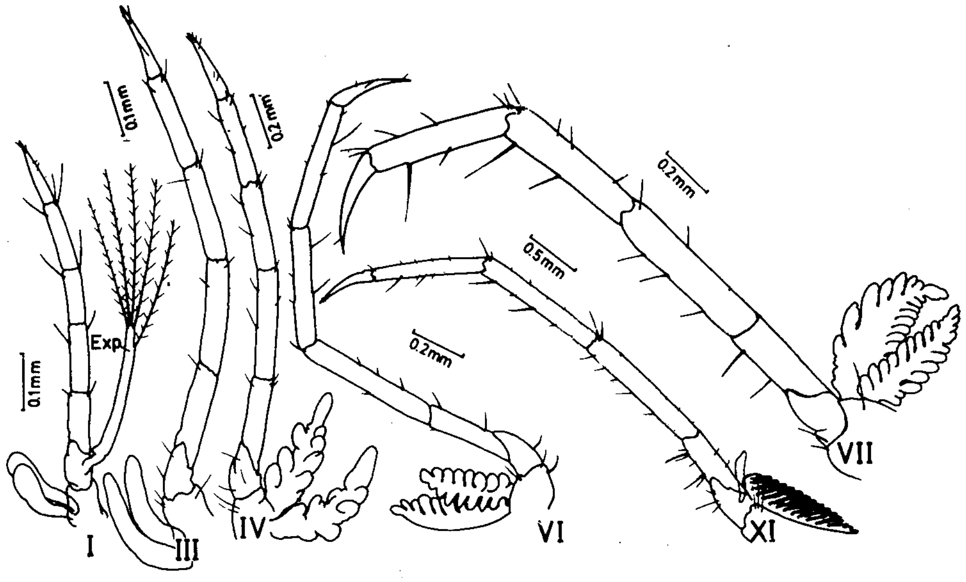

Fig. 54. Development of fifth pereiopod in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

pods do not form a chela, unlike those of the first three.

In the case of the 4th pereiopod, an arthrobranchia is present from the 1st substage, while a pleurobranchia has appeared by the 6th. In the case of the 5th pereiopod, the pleurobranchia is apparent at the 10th substage. The exopod lost in the 2nd substage reappears on the 4th pereiopod by the 10th substage, while the exopod on the 5th does not. The dactylus is blunt until the 3rd or 4th substage and thereafter becomes sharp and curved. The development of the 5th pereiopod is shown in Fig. 54.

First to fifth pleopods (Fig. 55)

The pleopods, the main locomotive organs after the mysis stage, become fully developed during the postmysis stage. Among the 5 pairs of pleopods, the 3rd is the most developed, while the 1st is developed slowly. In the case of the 3rd pleopod, for example, the number of plumose hairs increases at almost every molt, viz. 10, 12, 14, 16-18, 20-22, 24-30, corresponding to the 1st, 2nd, 3rd, 4th, 5th, and 6th substages, respectively, although there is a moderate variation observed in their number. At the 8th substage, the pleopod has a tiny inner branch (endopod), having one plumose hair. This branch gradually develops at every molt adding plumose setae on the periphery. The development of the 3rd pleopod is shown in Fig. 55.

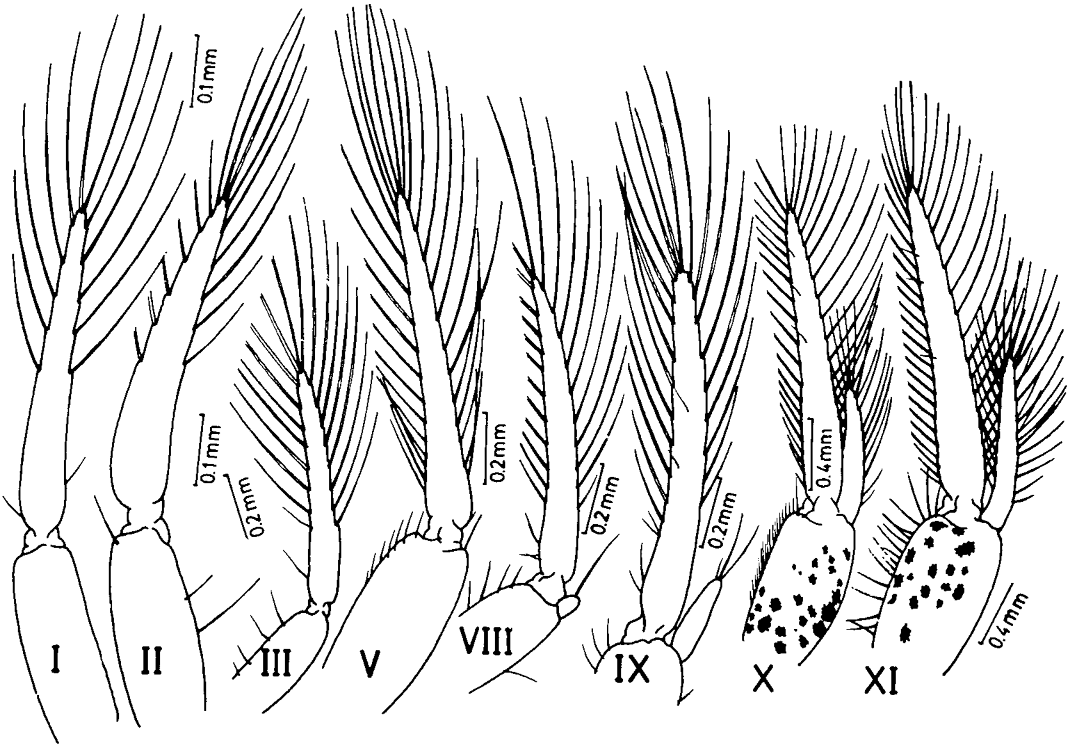

Fig. 55. Development of third pleopod in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

Abdomen, chromatophores and body form (Fig. 56)

The 1st substage has a small dorsal spine on the fifth abdominal segment, while none are present on the first four segments. Two lateral spines on the 5th segment are present in a few cases while in most specimens, they are absent. The two pairs of lateral spines on the 6th abdominal segment have disappeared, although a few specimens retain a pair of small ones. Once the prawns molt into the 2nd substage, these abdominal spines completely disappear.

During the 1st and 5th substages, the body appears slender when viewed laterally. This is particularly emphasized by dark brown chromatophores forming a streak from the tip of the antennular flagella through the ventral side of the abdomen to the tip of telson. After those substages, the body becomes more bulky and the chro-

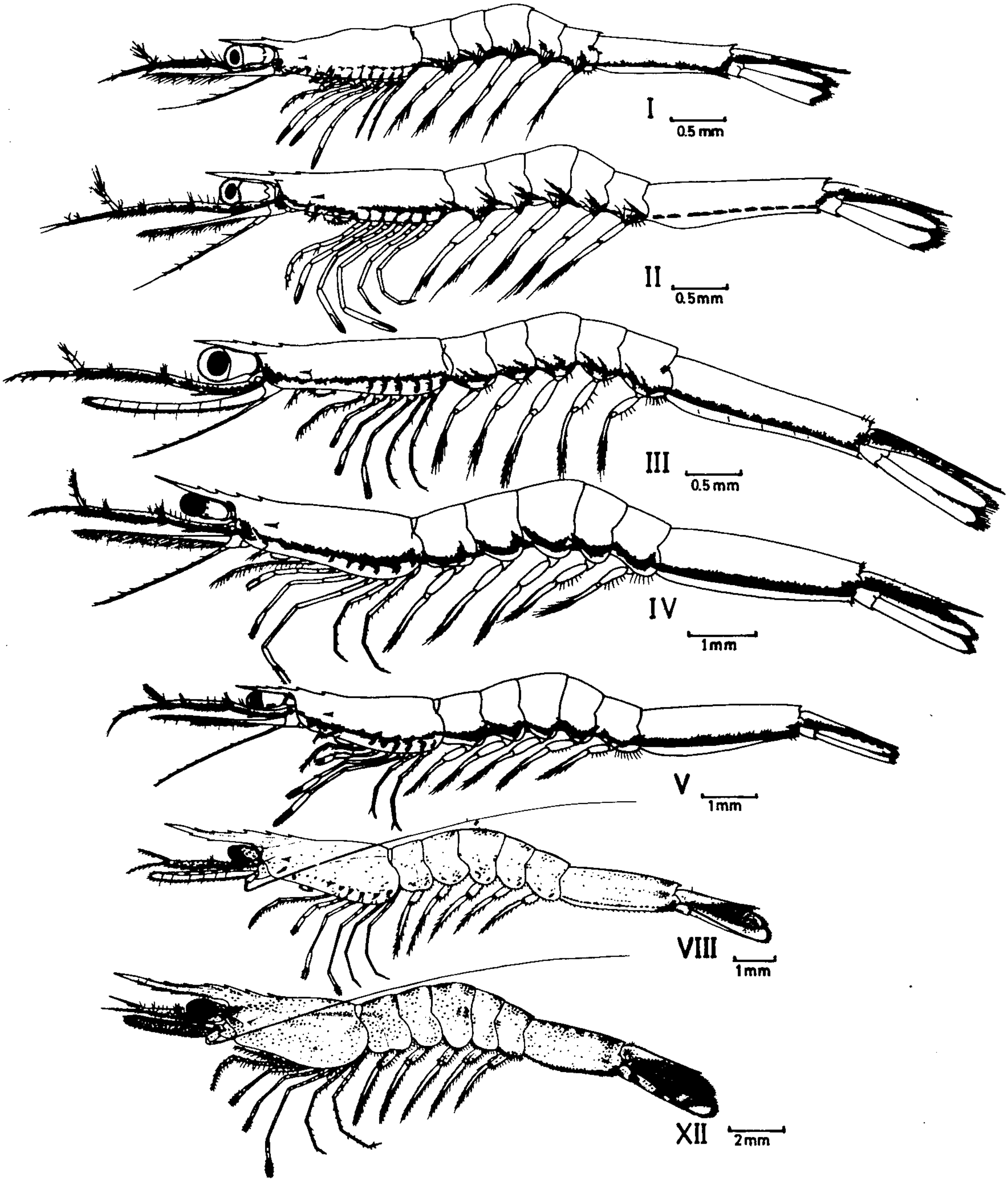

Fig. 56. Morphological development in postmysis *P. monodon*. Roman numerals denote substage of postmysis.

matophores begin to spread out over almost the entire body. Thus, hereafter, this substage may be called the beginning of the juvenile stage.

Branchial formation (Table 7)

There are 4 kinds of branchiae present as mentioned earlier, viz. arthrobranchia, mastigobranchia, podobranchia, and pleurobranchia. The arthrobranchiae appear at the 1st substage on all limbs from the 3rd maxilliped to the 3rd pereiopod, on the 4th pereiopod singly, while that on the 5th pereiopod is entirely absent during the postmysis substages. The mastigobranchia appears at the 1st substage on the 1st and 2nd maxillipeds and at the 12th substage on the 3rd maxilliped to 3rd pereiopod, while it is absent on the 4th and 5th pereiopods during the postmysis stage. A podobranchia appears on the 2nd maxilliped of the 2nd substage, but not elsewhere. One pleurobranchia appears on the 3rd maxilliped and on the successive 3 pairs of pereiopods at the 4th substage, on the 4th pereiopod at the 6th substage, and on the 5th pereiopod at the 8th substage. The number of the various branchiae above becomes the same as that in the adult prawn by the 12th substage. From the morphological point of view, it is observed that the branchial formula of the maxillipeds is more or less complete by the 4th substage. In addition, the tips (dactylus) of the 4th and 5th pereiopods in the 1st to 3rd substages are somewhat blunt with hairs, while after this period, they become sharply pointed and curved as mentioned earlier, suggesting adaptation of clinging to any objects. The branchial development is summarized in Table 7.

During the first three or four substages, the animals remain swimming and seldom cling to or rest on the bottom, while thereafter they rarely swim during daytime.

Of the above data the significant findings are that the branchial formulae are almost complete and a major morphological change occurs in the dactylus at the 4th substage. Furthermore, at the 3rd or 4th substage, the behavioral changes occur from planktonic to epibenthic.

Thus, it may be claimed that the first 3 or 4 substages of *P. monodon* following the mysis stage should be named megalopa, while the later juvenile stage.

Table 7. Branchial formula of postmysis *P. monodon* in order of mastigobranchia, podobranchia, arthrobranchia and pleurobranchia (from left to right).

Substage	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Adult
1st maxilliped	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
2nd maxilliped	1000	1110	1110	1110	1110	1110	1110	1120	1120	1120	1120	1120	1120
3rd maxilliped	0020	0020	0020	0021	0021	0021	0021	0021	0021	0021	0021	1021	1021
1st pereiopod	0020	0020	0020	0021	0021	0021	0021	0021	0021	0021	0021	1021	1021
2nd pereiopod	0020	0020	0020	0021	0021	0021	0021	0021	0021	0021	0021	1021	1021
3rd pereiopod	0020	0020	0020	0021	0021	0021	0021	0021	0021	0021	0021	1021	1021
4th pereiopod	0010	0010	0010	0010	0010	0011	0011	0011	0011	0011	0011	0011	0011
5th pereiopod	0000	0000	0000	0000	0000	0000	0000	0001	0001	0001	0001	0001	0001

Discussion

According to Hudinaga (1942), the branchial formula of the maxillipeds in *P. japonicus* is almost complete in the 4th postlarval (here "postmysis") stage. Oka (1968) found that in *P. orientalis* it is complete in the 5th postlarva. In the case of *P. monodon*, its branchial formula is completed by the 4th substage, similar to *P. japonicus.*

In *P. orientalis* the exopods of the 2nd maxillipeds during the 1st to 3rd substages are large with terminal hairs and are functional as locomotive organs. In addition, the distal 3 segments of the endopod are slender and bend inwards loosely during the first two substages, while in *P. japonicus* and *P. monodon* they are tightly bent inwards.

Kubo (1949) classified species of adult *Penaeus* into 3 subdivisions: *P. japonicus*-group, *P. monodon*-group, and *P. orientalis*-group. Pérez Farfante's (1969) classification is based on the morphology of the adult and she suggests 4 subgenera, viz. *Litopenaeus, Fenneropenaeus, Penaeus* s. s., and *Melicertus,* of which the first two are inconsistent prawns using terminology of Racek (1959), always on the move in the turbid water, while the *Melicertus* are consistent prawns preferring a well defined habitat, and the *Penaeus* s. s. belongs to an intermediate group from the morphological and ecological points of view.

According to Racek (1959), Pérez Farfante (1969) and Kurata (1978), *P. orientalis* belongs to the first group, *P. japonicus* to the *Melicertus* and *P. monodon* to the *Penaeus* s. s.

Thus, the differences in the development of the branchial formulae and the morphology of the endopod of the 2nd maxillipeds mentioned above might be an adaptation to different behavior and habitat during the respective stages.

During the observation of the postmysis under a microscope, malformation such as broken rostra and asymmetrical telsons of the reared specimens are often found particularly during the later substages, but never with the wild fry. Furthermore, morphological characteristics, such as the number of rostral spines, the shape of the telson, etc. are more or less complete, although the body size of the reared specimens are smaller than the equivalent substages of the wild ones. This phenomenon suggests that the metamorphosis of the reared animals may take place normally according to their age, while the body increment is inhibited due to unfavorable conditions.

Murano (1967) also reported that cultured larvae (phyllosoma of *Panulirus japonicus)* seem to grow more slowly than in the nature, as they have not yet been cultured under the conditions where they can attain normal development. This observation may also apply in general to larval and postlarval decapod crustacea such as penaeids.

During the later part of the present study, the wild specimens were used in preference to the reared ones to depict normal development for the reasons mentioned above. Thus, the classification of the 6th and advanced substages, and the mean carapace length were somewhat arbitrarily defined based on the morphological characteristics.

VIII-4 Adolescent, subadult and adult

Starting with the adolescent stage, the sex can be identified by a primitive petasma for male, or thelycum for female with a minimum size of 11 mm CL. The body proportion is almost same to an adult, although the length ratio (6th abdominal segment/carapace length) is more or less higher (0.68) than the adult (0.52).

A subadult is a commencement of sexual maturity with a maximum size of 37 mm CL for male and 47 mm CL for female. First copulation occurs during this stage.

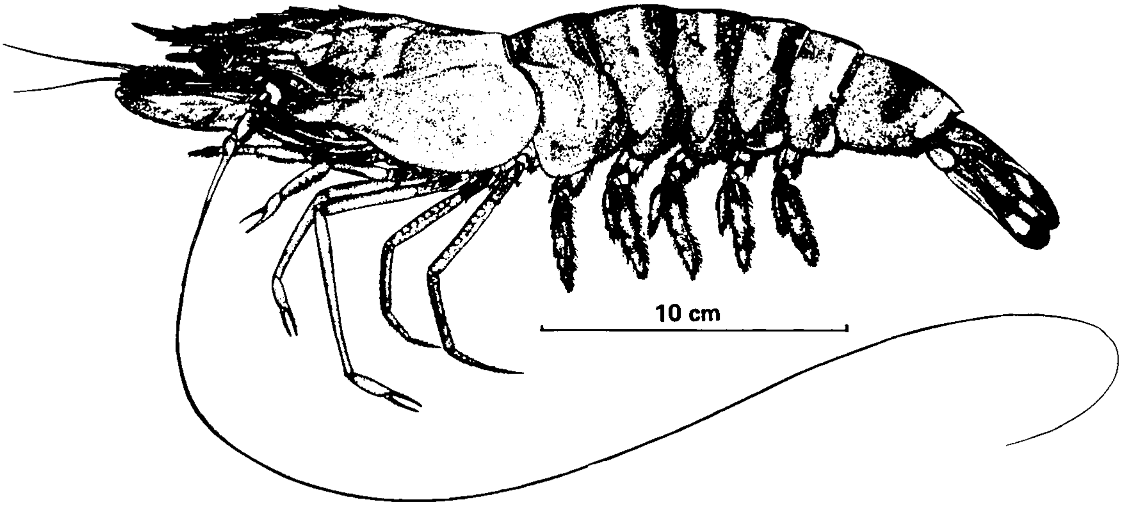

Fig. 57. Adult female of the giant tiger prawn, *Penaeus monodon* **FABRICIUS.**

An adult is the stage of completion of sexual maturity. Generally, females grow larger than males. (The morphology of the adult in detail is described in Section (IV-2.)

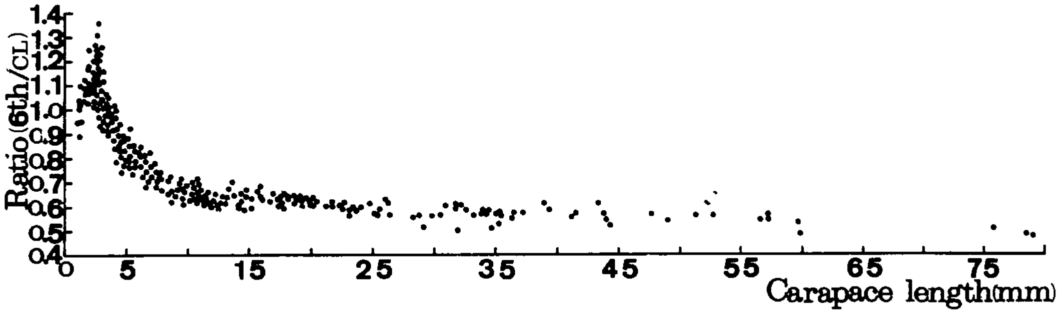

Fig. 58. The length ratio (length of 6th abdominal segment/carapace length) of *P. monodon* **from various areas.**

VIII-5. Life history phase

With research on ecology and life history, a need has arisen to standarize the criteria used to classify the developmental stage of prawns.

Based on the results of the previous sections, the life history of the giant tiger prawn is here divided into six phases: embryo, larva, juvenile, adolescent, subadult, and adult, following the method of Kurata (1973) for *P. japonicus.*

This stage is from fertilization through 2-celled, 4-celled, 8-celled, 16-celled, 32-celled, 64-celled, morula, blastula and gastrula up to hatching. It takes about 12 hours depending on the water temperature. The eggs are slightly heavier than sea water and sink to the bottom in still water.

B. Larva

The larval stage of *P. monodon* consists of 6 naupliar, 3 protozoeal, 3 mysis, and 3 or 4 megalopa substages and the times required for each stage is about 1.5 days, 5 days, 4-5 days, and 6-15 days, respectively. Swimming is by antennal propulsion in nauplii, antennal and thoracic propulsion in protozoea, thoracic propulsion in mysis and abdominal propulsion in megalopa. They are planktonic in behavior occurring offshore. Protozoea and mysis are collectively called zoea (Williamson, 1969). Furthermore, the megalopa as well as earlier juvenile stage is called postlarva traditionally or fry for commercial purpose. The body of the megalopa is transparent with a dark brown streak from tip of antennular flagellum to tip of telson.

The 6th abdominal segment is relatively longer than the carapace length. During the last substage of megalopa they enter a nursery ground. The carapace length of the megalopa varies between 1.2 and 2.2 mm.

C. Juvenile

During earlier juvenile, their bodies are partly transparent with a dark brown streak on the ventral side similar to the megalopa. They are traditionally, for convenience, called postlarva and/or fry in earlier stage and fingerling in later stage.

They differ from megalopa as follows: the 6th abdominal segment is relatively shorter compared to the carapace length and a greater body size, completion of rostral spine formula, the completion of gill system, and the benthic behavior. The ratio of the length of the 6th abdominal segment to the carapace length is still greater (about 0.65) than that in adolescent (about 0.58).

In the middle stage reaching about 2.7 mm CL, the body becomes blackish in color and the rostrum is furnished with 6 dorsal and 2 ventral spines. When it reaches about 3.7 mm CL, the body becomes more blackish and bulky morphologically and the rostrum is furnished with 7 dorsal and 3 ventral spines which is the same in adults. They crawl using pereiopods and swim using pleopods, the former becomes the main locomotive organ and the latter may be regarded as supplementary and used for rapid movement, both function through to the adult stage in the same manner, inhabiting brackishwater area as a nursery ground. The carapace length varies from 2.2 to 11.0 mm.

D. Adolescent

The body proportion is almost the same as that in the adult or slightly greater, with the ratio of the length of about 0.58. The sexes can be now identified, beginning at 11 mm CL. The carapace length of the adolescent varies between 11 and 34 mm. The minimum size of males possessing a jointed petasma is about 30 mm CL, and minimum size of females possessing adult-like thelycum is about 37 mm CL.

E. Subadult

This stage begins at the onset of sexual maturity, e.g. minimum male possessing spermatozoa in terminal ampoules, and minimum female possessing spermatozoa inside the thelycum through copulation.

A sex size disparity occurs at almost 30 mm CL, and hereafter the growth of females becomes greater than males. They migrate from nursery to spawning grounds. During this stage at estuarine or inner littoral areas before migrating to deeper water, the first copulation takes place between males with the minimum size of 37 mm CL and females of 47 mm CL.

F. Adult

This stage is characterized by the completion of sexual maturity. Males possess spermatozoa in the paired terminal ampoules, and in fact there are no sexual differences from subadult males apart from size increment and different habitat. Females start to spawn mostly offshore, whereas some spawn in shallow water (mouth of the bay down to almost 10 m deep). A second and/or more copulations may occur with majority of individuals. Their major habitat is the offshore area in depths to 70 m.

The maximum size of male ever found was 71 mm CL, whereas the length of female was 81 mm CL in the Philippines. Carapace lengths vary between 37 and 71 mm in male, and 47 and 81 mm in female.

The life history phases of the giant tiger prawn are summarized in Table 8.

As mentioned earlier, the nursery ground of the giant tiger prawn is in the estuaries which includes big brackishwater rivers (mostly upstream and middle portion), mangrove swamp, and interior portions of enclosed bays. These areas are exposed to wide fluctuations of physico-chemical conditions, such as water temperature and salinity, so that juveniles and adolescents should have great tolerances to

Table 8. Life history phases of the giant tiger prawn, *P. monodon.*

Phase	Begins at	Duration	Carapace length (mm) Male	Carapace length (mm) Female	Mode of life	Habitat
Embryo	Fertilization	12 hours	0.29*[1]		Planktonic	Outer littoral area
Larvae	Hatching	20 days	0.5-2.2		Planktonic	Outer/inner littoral area
Juvenile	Completion of gill system	15 days	2.2-11.0		Benthic	Estuarine area
Adolescent	Stability of body proportion, development of outer genitalia	4 months	11-30*[2],	11-37*[3]	Benthic	Estuarine area
Subadult	Commencement of sexual maturity, first copulation	4 months	30-37*[4],	37-47*[5]	Benthic	Inner/outer littoral area
Adult	Completion of sexual maturity	10 months	37-71*[6],	47-81*[6]	Benthic	Outer littoral area

*1 Egg diameter.
*2 Minimum size with jointed petasma.
*3 Minimum size with adult-like thelycum.
*4 Minimum size with spermatozoa in terminal ampoules.
*5 Minimum size with spermatozoa in thelycum.
*6 Maximum size ever found.

those conditions for their survival. Within those nursery grounds, however, the pressure of predators, particularly big finfish is generally not strong, unlike in the open sea, and more nutritional materials are available (Odum and Heald, 1972). According to the results of the present study (Fig. 121), mean monthly temperatures fluctuated between 26.3 and 31.2 °C, and salinity between 20.0 and 28.9 ‰, and both were extremely and suddenly lowered after heavy rain such as 24 °C and 4 ‰, respectively.

In general, the nursery ground has muddy substrata (Table 1) and is shallower, usually less than 6 m deep. Predation by fishes is probably a major cause of mortality of juvenile giant tiger prawn as well as other penaeids.

VIII-6. Development of external genitalia

The present part deals with the description of the morphological development of the external genitalia of *P. monodon.*

Morphometric measurements were patterned after the method of Tuma (1967). The sizes of the prawns in the present paper refer to carapace length (CL). Measurements were made with sliding calipers capable of being read to 0.1 mm. The length of petasma was measured as the median linear distance between the anterior and posterior margins of the organ. The length of thelycum was measured along the median aperture as the linear distance between the anterior edge of the boss-like anteromedian plate and the posterior margin of the lateral plates. The thelycum width is the greatest distance between the two lateral plates.

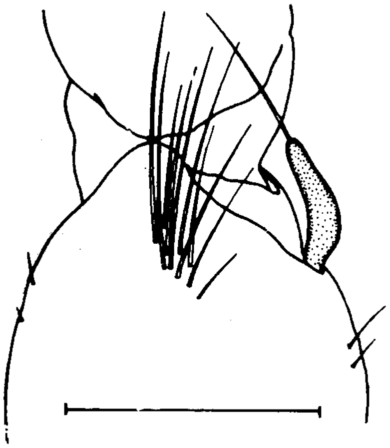

Fig. 59. Bud of endopod of the first pleopod (7.2 mm CL). Scale represents 0.5 mm.

Result and discussion

In the specimen as small as about 7 mm CL, the modified endopod of the first pair of pleopod is only a minute tubular outgrowth located slightly below the base of the exopod, thus the sexes cannot be distinguished. It is equipped in most specimens with a single apical hair or seta at the tip of its middle portion (Fig. 59). The sex of male specimens of about 11 CL can be distinguished microscopically by the rudimentary appendix masculina (Fig. 60A) and the relatively narrower space between the base of the 4th and 5th pereiopods (Fig. 60B). Females of equivalent length can be distinguished by the appendix masculina-like bud (Fig. 60C) and the wider space of the thelycum between the base of the 4th and 5th pereiopods (Fig. 60D).

Petasma

Specimens measuring about 11 mm CL possess a small rudimentary petasma in the form of a knife-shaped projection situated at subapical portion of protopod (Fig. 61A). At about 22 mm CL, the petasmal endopod has grown almost twice in length and is more or less triangular in shape with a broad posterior portion and narrow but rounded anterior tip. A few minute hooks are visible along the inner

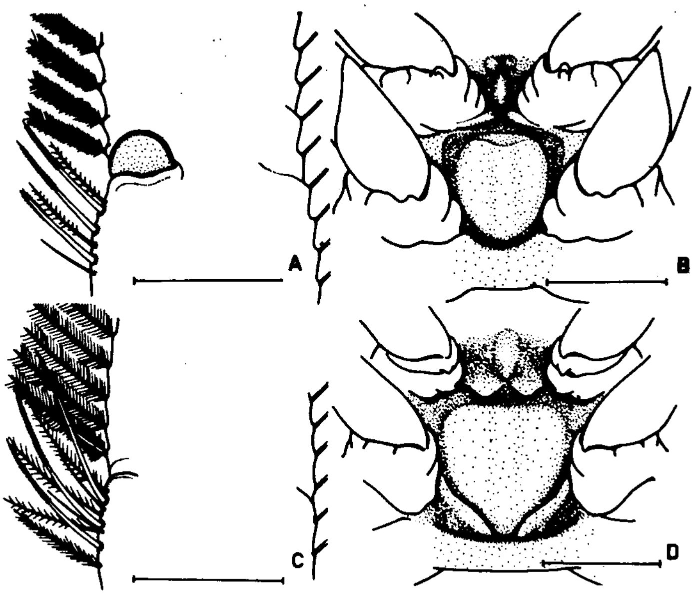

Fig. 60. Bud of appendix masculina (A) and narrower space between 4th and 5th pereiopods (B) in male (10.8 mm CL), and primitive tubercle on the 2nd pleopod (C) and the thelycum (D) in female (11.3 mm CL). Scales for A and C represent 0.25 mm, and for B and D, 1 mm.

border (Fig. 61B). At about 24 mm CL the relatively flat triangular-shaped wing of the petasma disappears due to the formation of a slight fold indicating the formation of the median and lateral lobes. The number of median hooks increases sharply more or less rectangular in profile, the petasma sits on a narrow stalk-like tubular portion (Fig. 61C). At about 31 mm CL, the modified endopod closely resembles the petasma of the adult. The inner margin is now lined with numerous minute hooks, but, at this stage both petasmal endopods of the first pair of pleopods are still rather small and do not meet at the midline but remain separated as two identical components. The tip of the ventral lobule is slightly folded inward forming a fishing hook-like margin and is relatively thickly calcified, very much like the petasma of *P. indicus* as described by George and Rao (1968). A few small bristles appear on the inner anterior marginal surface (Fig. 61D). When the prawn reaches about 34 mm CL, the petasma has almost assumed the adult form and character. The two halves are now large enough so that their inner margins meet at the median line and are thus united or fused together with the aid of the numerous minute hooks. However, the two components can be easily separated by physical force. The number of bristles increases on the inner surface of the lateral lobe. Both the median and lateral lobes as well

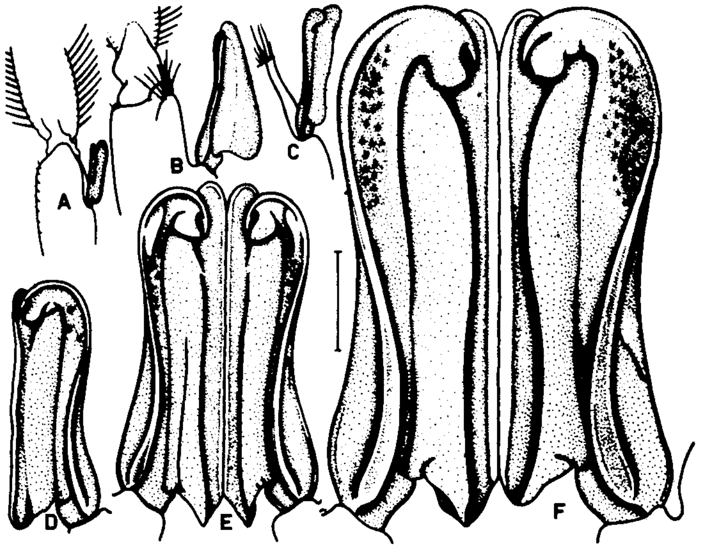

Fig. 61. Development of petasma. A, 11.2 mm CL; B, 21.6 mm CL; C, 23.5 mm CL; D, 26.9 mm CL; E, 34.2 mm CL; and F, 46.8 mm CL. Scale represents 2 mm.

as the inwardly curved hook-like tips of the latter become more pronounced (Fig. 61E). As the animal attains 47 mm CL, the distal tips of the lateral lobes become very much enlarged, curved inward and overlying the median dorsal lobes more medially. More than 20 anteriorly directed bristles are distributed on the inner surface, however, the posterior half portion of the petasma lacks bristles (Fig. 61F). There is practically no morphological change in the shape of the petasma hereafter, except for an increase in size in relation to the growth of the animal. The two petasmal components are relatively firmly fused together along the median line. It seems, however, that there is no further increase in the number of bristles as the prawn grows. A cross-section of an adult petasma shows that the median lobes are relatively thin and membraneous, the lateral lobe is by contrast stiff, thicker and well calcified. Ridges along its margin help to provide the necessary structural stiffness of the organ. In the posterior section it is clearly visible that the median lobe of each component forms a more or less median tuberculated space which lies ventrally as viewed in its normal position on the animal body (Fig. 62).

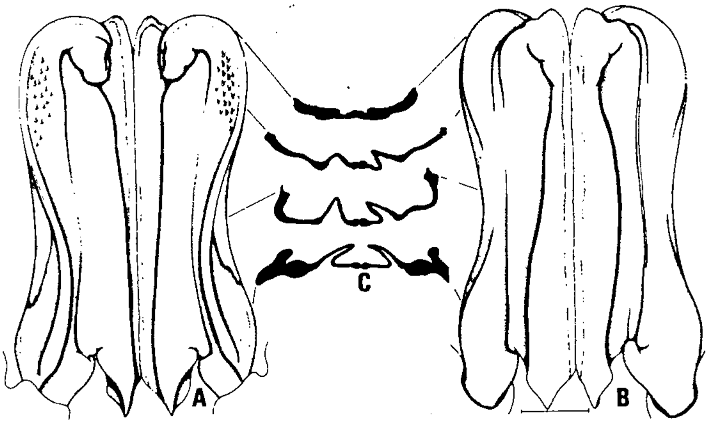

Fig. 62. Ventral (A) and dorsal (B) views of adult petasma (50.8 mm CL), and its transections (C). Scale represents 2 mm.

The relationship between carapace length and petasma length derived from the least square method is shown as follows: PL = –3.5075 + 0.3025 CL, where CL is the carapace length and PL, petasma length in mm (N = 177, r = 0.9521). (Fig. 65).

Appendix masculina

The shape of the appendix masculina located on the endopod of the second pleopod, is generally oval or pear-shaped. However, its size and the number of strong spines along the margin increase in accordance with the growth of the prawn.

At about 11 mm CL, the appendix masculina is merely rod-shaped devoid of any setae or spines. When the carapace length reaches about 22 mm, the appendix masculina becomes stout armed with 4 or 5 spines.

Later development of the appendix masculina involves only increases in size and number of spines, as shown in Fig. 63, whereby the strong spines along its outer and distal margins give the appearance of animal-claws.

Thelycum

The development of the thelycum in this species follows principally the same patterns as established for *P. indicus* by George and Rao (1968) and for several *Penaeus* species described by Kubo (1949).

At about 11 mm CL, the median plate is discernible as a small elevation between the 4th and 5th pereiopods (Fig. 64A). The lateral plates are rudimentary but nevertheless recognizable as a pair of elongated triangular plates between the 5th pereiopods at a size of 15 mm CL (Fig. 64B).

At about 22 mm CL, the lateral plates are further enlarged and broadened but are still widely spaced (Fig. 64C). Further development of the plates is observed at about 32 mm CL when the median plate appears as a raised portion with an elevated round apex. The anterior portion of the lateral plates extends further and begins to overlap the lateral flanges of the median plate. The antero-medial margin of the lateral plate is slightly raised (Fig. 64D).

As the prawn grows to 37 mm CL, the lateral plates become broader and extend further anteriorly and medially completely overlapping the lateral sides of the median plate and leaving only a V-shape slit between them. The lateral plates become crescent-shaped with a space at the anterior base. The lateral plates still form a more or less flat surface (Fig. 64E).

When the prawn reaches about 47 mm CL, the thelycum assumes completely its adult form. The two lateral plates have thickened considerably (Fig. 64F) with a distinct elevation in the inner lateral margin and occupy almost

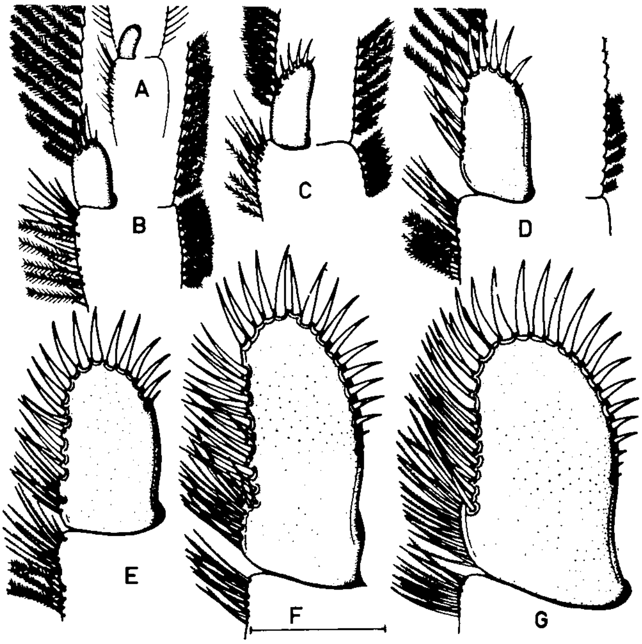

Fig. 63. Development of appendix masculina. A, 11.2 mm CL; B, 21.6 mm CL; C, 23.5 mm CL; D, 31.5 mm CL; E, 33.2 mm CL; F, 47.0 mm CL; and G, 50.8 mm CL. Scale represents 1 mm.

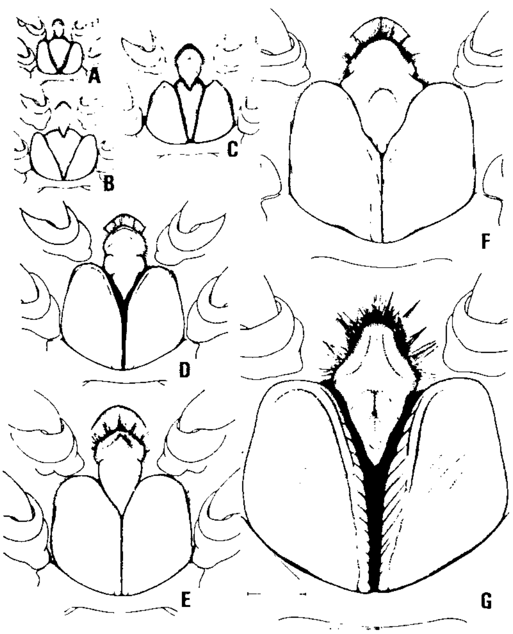

Fig. 64. Development of thelycum. A, 11.7 mm CL; B, 15.2 mm CL; C, 22.4 mm CL; D, 31.4 mm CL; E, 36.5 mm CL; F, 46.8 mm CL; and G, 62.6 mm CL. Thelyca F and G are inseminated. Scales represents 2 mm.

the entire space between the sternite of the 5th pair of pereiopods. The lateral plates grow slightly broader posteriorly and meet each other in the median line, while the edges of the plates form an elevated ridge. Externally a V-shaped slit is formed from the median and lateral plates. A concealed hollow space beneath the median plate is formed by the over-hanging posterior shelf-like extension, visible only upon dissection of the organ.

There is a linear relationship between the size of the prawn and its petasma or thelycum as shown in Fig. 65.

The relationships between the carapace length and thelycum length, and carapace length and thelycum width for *P. monodon* are expressed as follows:

TL = –0.8147 + 0.1878 CL, where CL is carapace length and TL, thelycum length in mm (N = 222, r = 0.9322).

TW = – 0.7565 + 0.1648 CL, where CL is carapace length and TW, thelycum width in mm (N = 223, r = 0.9287). (Fig. 65).

Discussion

At approximately 34 mm CL in male *P. monodon*, the petasma is structurally complete in the great majority of specimens, and corresponds to be functional as an intermittent organ. In female *P. monodon*, the thelycum is structurally complete in almost all animals above 47 mm CL, corresponding to a functional genitalia.

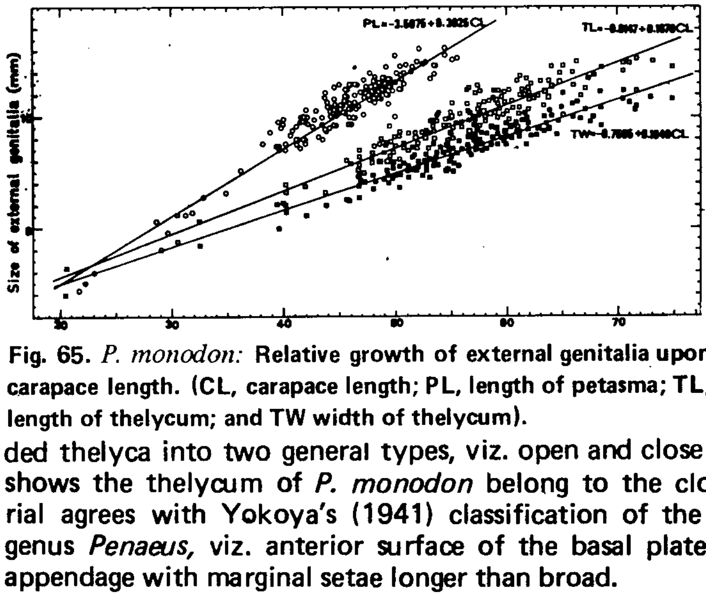

Fig. 65. *P. monodon:* Relative growth of external genitalia upon carapace length. (CL, carapace length; PL, length of petasma; TL, length of thelycum; and TW width of thelycum).

According to the author's own observation, a similar gap between sexes mentioned above may be common to other species of the genus *Penaeus,* but no data have yet been published.

Tuma (1967) divided thelyca into two general types, viz. open and close types, and the present study shows the thelycum of *P. monodon* belong to the close type. The present material agrees with Yokoya's (1941) classification of the appendix masculina of the genus *Penaeus,* viz. anterior surface of the basal plate without strong elevation, appendage with marginal setae longer than broad.

VIII-7. Identification of postlarval *Penaeus*

Prawirodihardjo *et al.* (1975) studied postlarval *P. merguiensis, P. monodon,* and *P. semisulcatus* in Indonesia.

In the Philippines, it has been observed that fry collectors and concessionaires sometimes misidentify the postlarvae caught at the coastal waters or mangrove areas. At present, however, there is no published literature on the identification of the postlarval *Penaeus* in this country. This part deals with the identification of commercially important postlarval *Penaeus* appearing at shore waters.

Materials for the present study consisted mainly of postlarvae collected with the use of a triangular push net from inshore waters during daytime at Villa and Tigbauan, and hatched larvae of identified species reared in the laboratory.

Result and discussion

Identification of the postlarvae of *Penaeus* is here based on morphological characteristics such as the shape of the rostrum, the number of rostral teeth, the relative length of antennular flagella, the antennal spine and the presence of dorsal carinal spinules on the 6th abdominal segment. The chromatophore patterns on the 6th abdominal segment and on the telson plus uropods were also useful for identification, especially when materials were alive or still fresh.

At present, there are seven known species of the genus *Penaeus* found around Panay Island and its adjacent waters. These are *P. monodon, P. semisulcatus, P. merguiensis, P. indicus, P. japonicus, P. latisulcatus* and *P. longistylus* (Motoh and Buri, in preparation).

The postlarvae of all species except *P. longistylus* were also obtained from gravid females of known parentage in the laboratory. It was, however, observed from larval rearing experiments that the larvae of *P. merguiensis* and *P. indicus* are morphologically similar to each other. The same applies to *P. japonicus* and *P. latisulcatus* (and probably *P. longistylus* because of the morphological similarities of the adults). The species are, therefore, still arbitrarily combined as two groups viz. *P. merguiensis* group and *P. japonicus* group, as no substantial morphological differences have been found.

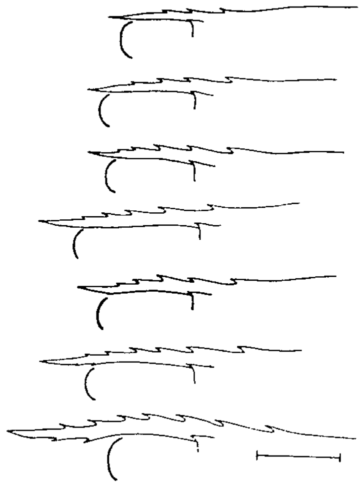

Fig. 66. Variations of rostral spine of postlarval *P. monodon*. Scale represents 1 mm.

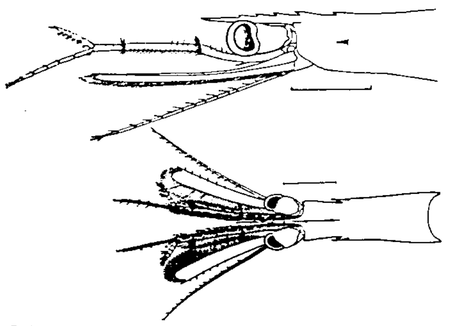

Fig. 67, Anterior portion of postlarval *P. monodon*. Upper, lateral view; lower, dorsal view. Scale represents 1 mm.

A. *P. monodon*

The postlarvae of *P. monodon* are the largest among all the species. It is easy to pick them up among all postlarvae because of the dark brownish red streak along their entire abdominal length extending from the tip of the inner antennular flagellum to the tip of the telson. The inner (lower) antennular flagellum consisting mostly of six to seven segments is more than twice as the outer (upper) flagellum. The outer flagellum consists of four to five (or rarely six) segments. The former has dark brown or reddish brown chromatophores, while the latter has usually none.

The 6th abdominal segment lacks dorsal carinal spinules and is longer than the carapace in the great majority of specimens. The telson and inner half of the endopods of the uropods are heavily pigmented from the proximal to the distal portions. The number of chromatophores lined ventrally along the 6th abdominal segment is more than 13, and these are usually densely distributed forming almost a continuous pattern. Chromatophores on the antero-lateral margin of the 6th abdominal segment are usually absent. The rostrum is straight or bent slightly upward at its tip, and is 0.4 to 0.5 times the length of the carapace. The number of teeth on the rostrum is mostly four to five dorsally and none or one ventrally. The antennal spine is absent.

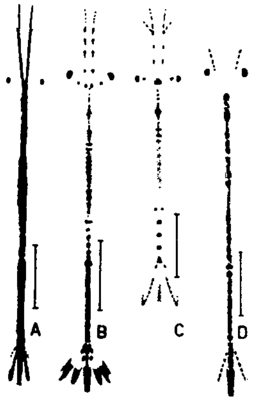

Fig. 68. Dorsal view of postlarval *Penaeus* showing chromatophore pattern for quick identification. A, *P. monodon;* B. *P. semisulcatus;* C, *P. merguiensis* group; D, *P. japonicus* group. Scales represent 2.5 mm.

B. *P. semisulcatus*

The postlarvae of *P. semisulcatus* are relatively smaller and have an up-tilted rostrum with mostly six dorsal and no ventral spines. The inner antennular flagellum has five or rarely six segments and is 1.7 to 2.0 times the length of the outer flagellum. Rostrum length is 0.5 to 0.8 times the length of the carapace. The rostrum is furnished with five to six dorsal teeth and one or two ventral teeth. The antennal spine is very small or absent.

In general appearance, this postlarva is closely similar to *P. monodon*. However, it may be different by several characteristics as shown in Table 9.

Table 9. Comparison of the postlarval characteristics of *P. monodon* **and** *P. semisulcatus*.

Characteristics	P. monodon	P. semisulcatus
Carapace length*	Mostly longer than 2.2 mm	Mostly shorter than 2.2 m
Inner antennular flagellum	More than twice of the outer	Equal or less than twice of the outer
Rostrum	Straight or slightly upward	Up-tilted
Sixth abdominal segment	Longer than carapace length	Less or as long as carapace length
Chromatophores in the middle portions of telson and inner uropods	Present	Absent
Antero-lateral chomatophore on the 6th abdominal segment	Absent	Present
Number of chromatophores along the 6th abdominal segment	More than 13 (mostly continuous)	6 to 12

*Considerable variations occur.

C. *P. merguiensis* group

Adults are well known as "white shrimp" or "banana prawn". The postlarvae of *P. merguiensis* and *P. indicus* are translucent and indistinctly pigmented. The inner antennular flagellum of the postlarvae consisting of four or five segments is 1.4 to 1.5 times the length of the outer flagellum which consists of four (rarely three or five) segments. Both the inner and outer flagella are relatively stout, often unpigmented, not similar to those belonging to other groups. Chromatophores on the antero-lateral margin of the 6th abdominal segment are present. The rostrum is very long with its anterior two-thirds toothless. It is perfectly straight and is 1.4 to 1.5 times the carapace length. The number of spines on the rostrum is mostly three or four dorsally and none ventrally. The antennal spine is absent.

In older individuals, however, the rostrum becomes progressively more attenuated and bent slightly upwards having a maximum of six to seven dorsal teeth and three to six ventral as is also the case in adults.

D. *P. japonicus* group

The postlarvae of this group consist of *P. japonicus, P. latisulcatus* and probably *P. longistylus.* They are readily distinguished from others by the following characteristics:

1) The rostrum is short, only 0.2 to 0.3 times the carapace length, and does not extend beyond the tip of eye.
2) The dorsal rostral teeth are closely spaced.
3) The dorsal carina on the 6th abdominal segment possesses several rows of prominent spinules.
4) Antennal spine is conspicuous.

Generally, it resembles closely the postlarvae of *P. monodon* because both have the longitudinal streak of dark brown or dull green chromatophores. However, even local fry collectors can, by eye, skillfully distinguish the postlarvae of *P. japonicus* group from *P. monodon* because of their smaller size and slightly stouter body. Chromatophores on the antero-lateral margin of the 6th abdominal segment are usually absent.

The rostrum is robust and is furnished with five to seven dorsal teeth, but no ventral teeth. The chromatophores on the 6th abdominal segment are very numerous and confluent.

The inner antennular flagellum is 1.4 to 1.8 times the length of the outer flagellum.

Key to the postlarval *Penaeus* appearing at the shore waters, based on morphological characteristics.

1) Rostrum stout and not reaching tip of eye; spinules on the 6th abdominal segment present; antennal spine prominently present; carapace slightly longer than 6th abdominal segment. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ *P. japonicus* group

Rostrum slender and extending beyond tip of eye; spinules on 6th abdominal segment absent; antennal spine absent or minute; carapace slightly or distinctly shorter than 6th abdominal segment. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ 2

2) Inner (lower) antennular flagellum nearly 1.6 times as long as outer (upper) flagellum, exceeding the latter by one distal segment. _ _ _ *P. merguiensis* group.

Inner antennular flagellum 1.6 to 2.0 times as long as outer flagellum, exceeding the latter by two distal segments. -------------- *P. semisulcatus.*

Inner antennular flagellum more than 2.0 times as long as upper flagellum, exceeding the latter by three distal segments. --------------- *P. monodon.*

Key to the postlarval *Penaeus* appearing at the shore waters, based on chromatophore pattern.

1) Number of chromatophores on the 6th abdominal segment less than seven; antero-lateral chromatophore of the 6th abdominal segment present. --- *P. merguiensis* group

Number of chromatophores on the 6th abdominal segment more than seven; antero-lateral chromatophore of the 6th abdominal segment absent except *P. semisulcatus.* -- 2

2) Number of chromatophores on the 6th abdominal segment less than twelve; chromatophores on the middle portion of the telson and inner uropods absent; antero-lateral chromatophore of the 6th abdominal segment present. --- *P. semisulcatus.*

Number of chromatophores on the 6th abdominal segment more than twelve; chromatophores on the middle portion of the telson and inner uropods present; antero-lateral chromatophore of the 6th abdominal segment absent. ---3

3) Chromatophores on the 6th abdominal segment dense and thickly continuous. -- *P. monodon*

Chromatophores on the 6th abdominal segment each separate or confluent. -- *P. japonicus* group.

Subrahmanyam and Rao (1969) and Rao and Gopalakrishnan (1969) pointed out the importance of the number of chromatophores on the 6th abdominal segment for the identification of postlarval *Penaeus* in India. This character is also applicable to the present materials in the Philippines. The method of identification by way of chromatophores is useful for live materials and for specimens preserved in 5 % formalin for up to three months.

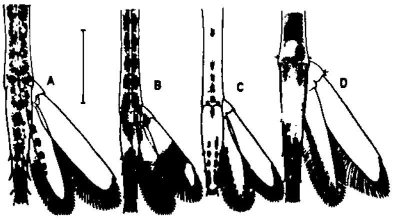

Fig. 69. Dorsal view of sixth abdominal segment, telson and uropods of *Penaeus* postlarvae showing chromatophore patterns. A, *P. monodon*; B, *P. semisulcatus*; C. *P. merguiensis* group; D, *P. japonicus* group. Scale represents 1 mm.

Some of the criteria presented here may not be applicable for very young postlarvae occurring in offshore waters and for older or more advanced postlarvae or juveniles from brackishwaters and mangrove areas. Therefore, it may be necessary to provide another key for these specimens.

It was observed that the colors of chromatophores distributed on the inner antennular flagella, abdomen, sixth abdominal segment, telson and uropods varied from red, yellowish brown, greenish brown to dark brown in all materials examined and color does not appear to be species constant.

In finding the morphological differences between *P. merguiensis* and *P. indicus* and among *P. japonicus, P. latisulcatus* and *P. longistylus,* it is nevertheless recommended to rear and observe keenly not only the postlarvae but also the larvae from known parentage.

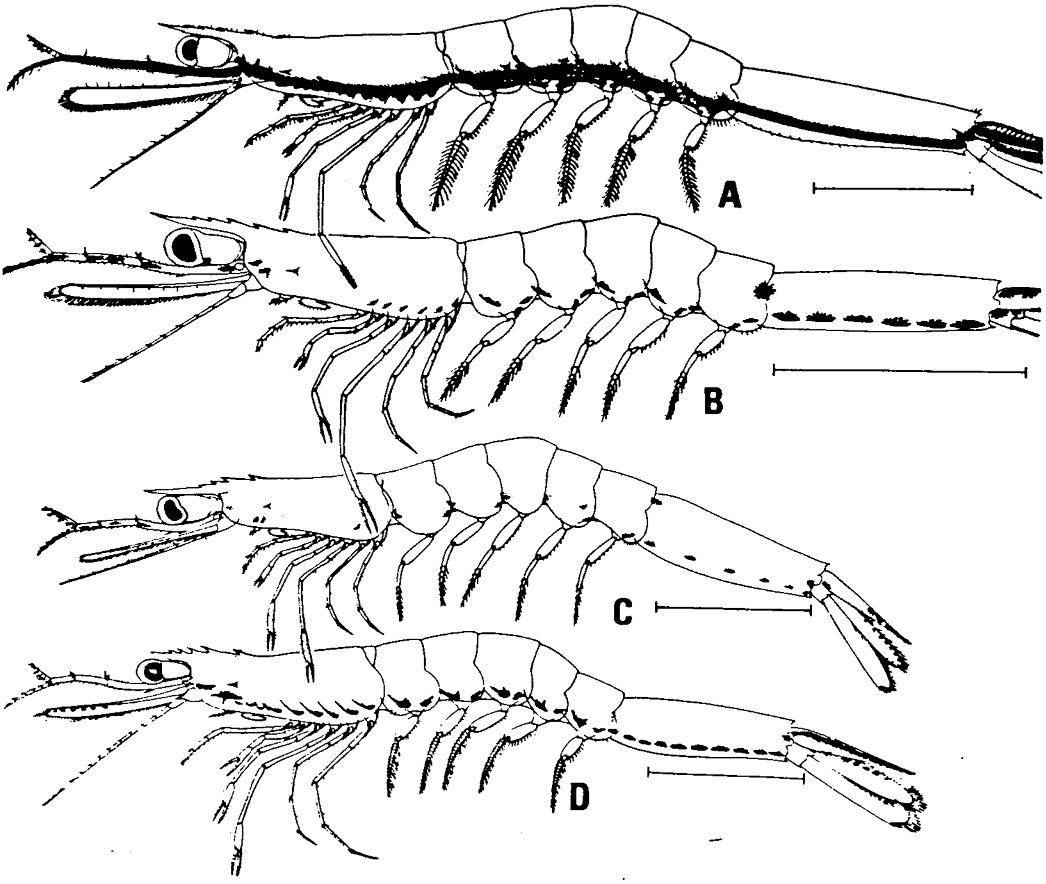

Fig. 70. Lateral view of *Penaeus* postlarvae showing chromatophore patterns. A, *P. monodon*; B, *P. semisulcatus*; C, *P. merguiensis* group; D, *P. japonicus* group. Scales represent 2 mm.

IX. GROWTH

To estimate the growth rate and the molting frequency, prawns were reared, fed on trash fish, in addition to natural feed in earthen ponds. In the laboratory experiments, each stage was accommodated as follows: one *l* beaker for megalopa, 50 *l* glass aquaria for juvenile, 200 *l* fiber reinforced plastic (FRP) tanks for adolescent or subadult located at the biology/wet laboratories. Enough food, such as live adult brine shrimp (*Artemia*) and mussel or fish meats, were given daily. The following morning, the remaining food was taken out. A certain amount of rearing water was exchanged from time to time. Light conditions were ambient.

Salinity was gradually lowered and water temperature was ambient in all rearings. Salinity ranged between 6 and 33 °/oo, whereas water temperature was 26 and 30 °C.

IX-1. Growth of *P. monodon*

The data on the increase in the linear dimension at molting gave a straight line, if the premolt dimension on the X axis is plotted against the postmolt dimension on the Y axis (Kurata, 1962). This relation was found to apply to *P. monodon* reared under experimental conditions.

The straight line is expressed as:

$Ln + 1 = a + b\ Ln$, where Ln and Ln + 1 are linear dimensions before and after a molt respectively, and a and b are constants. The constant denotes a coefficient with which the successive amounts of postmolt increment vary based on data shown in Table 10.

Table 10. Average carapace lengths, absolute and percentage increments, and their ranges for *P. monodon*. Data pooled for four experiments, 1978-1979.

Premolt CL (mm)	No. Observed	Mean CL (mm)		Mean increment		Range	
		Premolt	Postmolt	(mm)	(%)	Premolt CL (mm)	Increment (mm)
1 - 5	95	3.5	3.9	0.4	11.4	1.8 - 5.3	0.1 - 1.7
6 - 10	91	7.2	7.7	0.5	6.9	5.5 - 10.1	0.1 - 1.6
11 - 15	29	10.6	11.3	0.8	6.8	10.5 - 14.4	0.1 - 3.6
16 - 20	5	19.3	19.5	0.2	1.0	18.3 - 20.1	0.1 - 0.5
21 - 25	15	22.1	22.6	0.5	2.3	20.7 - 24.8	0.2 - 1.4
26 - 30	12	26.9	27.3	0.4	1.5	25.6 - 28.7	0.1 - 0.9
31 - 35	2	32.0	32.1	0.2	0.6	31.8 - 32.1	0.1 - 0.2
36 - 40	3	37.2	40.3	3.2	8.6	35.2 - 39.2	0.4 - 0.8

The linear line obtained was as follows:

$Ln + 1 = 0.69 + 1.01\ Ln$, ($r = 0.997$, $P<0.001$, $df = 73$)

where Ln + 1 and Ln are carapace length in mm.

It was found by Kurata (1962) that the interval between molts consists of two portions: one is a basic period which remains constant for practically all sizes of the animal, and the other is an additional period which is proportional to the volume of the animal. Accordingly it may be expressed as follows (Kurata, 1962):

$D = do + K L^3$, where, D is the time interval between molts, L is the length (carapace length in the present study), do is constant, the basic period, and K is a constant and denoting the volume coefficient of the additional period of requirement. Based on the data obtained, the linear equation is $D = 8.33 + 4.55 L^3$ ($r = 0.461$, $P < 0.001$, $df = 190$), where D is time in day and L is carapace length in mm. However, the relationship $D = 3.10 + 0.66 L$ gave a higher coefficient of correlation ($r = 0.727$, $P < 0.001$, $df = 190$) within the present experiment.

According to the data obtained in the laboratory and from prawn culture ponds (Fig. 76), *P. monodon* juveniles grow to about 1 g in body weight within one month after metamorphosis to postlarvae and after this period the growth curve shows a sharp increase. The growth disparity between sexes begins 2.5 months later. The females show more rapid growth than the males, and about 4 months later they become sexually mature, big enough for commercial (eating) purposes. Some of them, particularly the largest male may survive for about one and half years and the longest female about two years judging from the carapace length distribution of the wild prawns caught, although this is hypothetical.

The body (total) length-carapace length relationship was calculated by the least square method, based on 180 postlarvae, 83 males and 73 females as follows and are shown in Figs. 71 and 74.

a) Postlarvae (megalopa and juvenile)
   $TL = -2.9 + 6.21\ CL$ ($r = 0.935$)

b) Adolescent to adult

Male, $BL = 11.8 + 3.31\ CL$ ($r = 0.983$); Female, $BL = 22.8 + 3.00\ CL$ ($r = 0.990$), where CL is carapace length in mm and BL, body length in mm.

The regression coefficient of log body weight on carapace length was also calculated by the least square method for 383 males and 383 females as follows and shown in Fig. 72.

Male, $\text{Log } BW = -2.7 + 2.71 \text{ Log } CL$ ($r = 0.982$)

Female, $\text{Log } BW = -2.6 + 2.65 \text{ Log } CL$ ($r = 0.990$), where CL is carapace length in mm; BW, the body weight in g and r, coefficient of correlation.

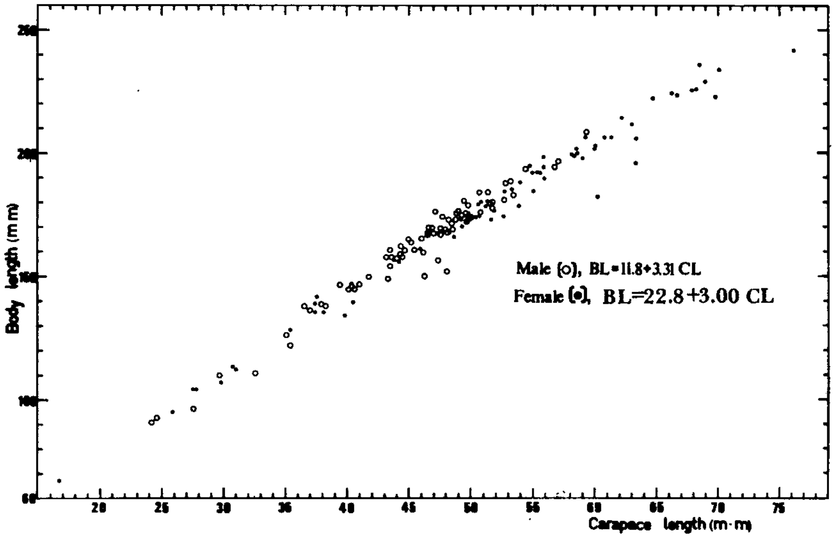

Fig. 71. Relationship between carapace length and body length of *P. monodon* collected from Panay Island, from 1976 to 1978.

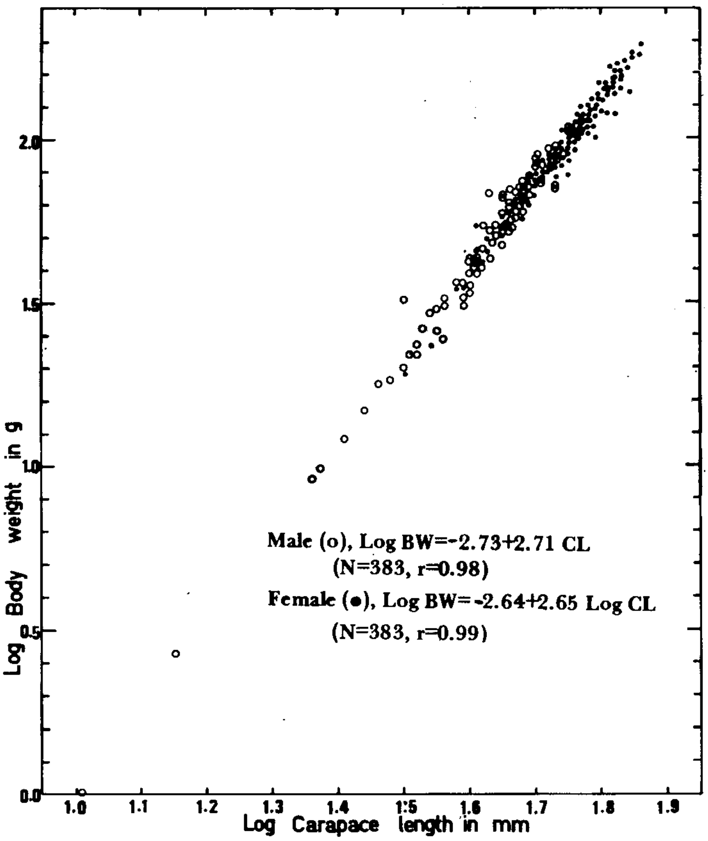

Fig. 72. Relationship between carapace length and body weight of *P. monodon* collected from Panay Island, from 1976 to 1978.

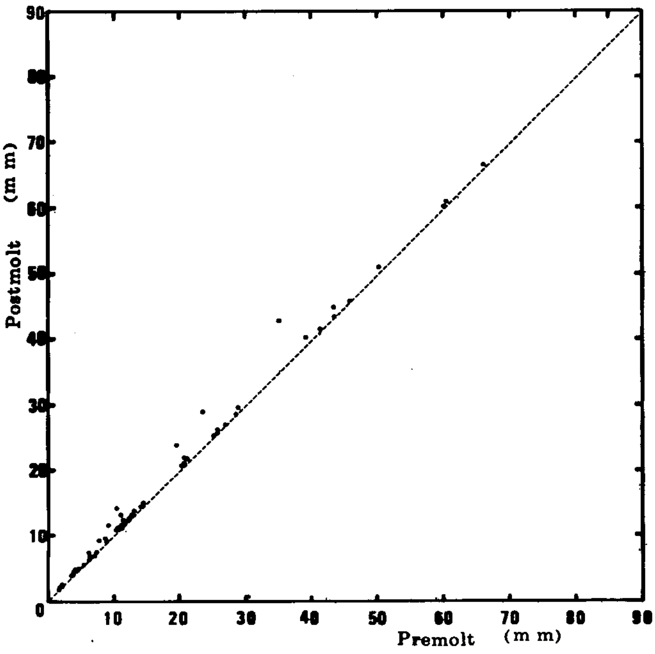

Fig. 73. Hiatt's growth diagram for *P. monodon* in captivity. A broken line represents a diagonal.

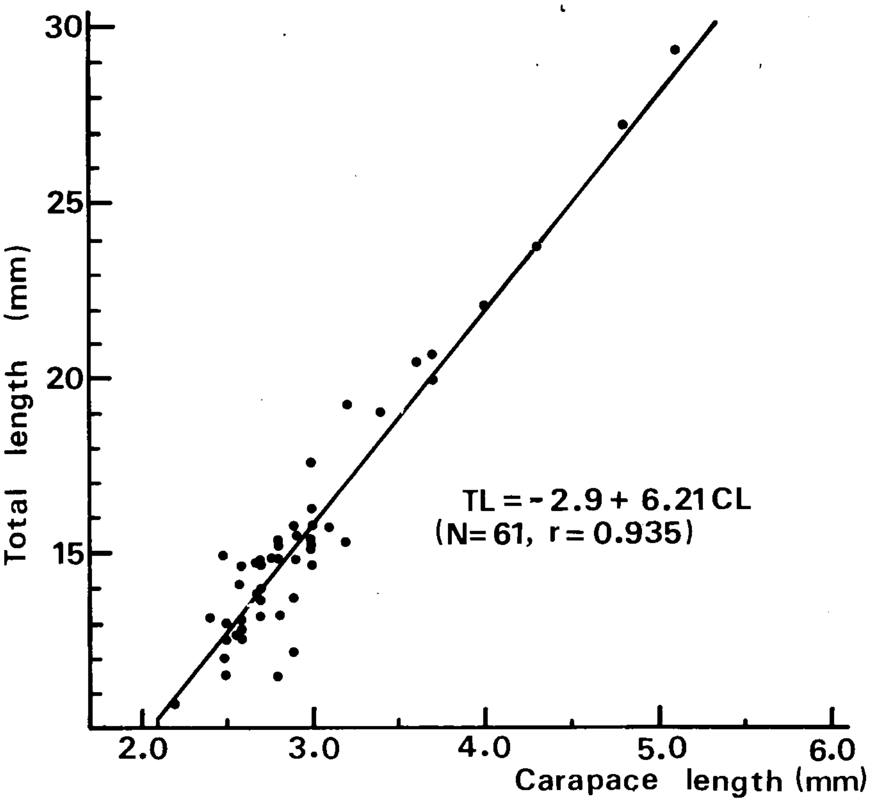

Fig. 74. Correlation between carapace length and total length of *P. monodon* postlarvae caught with fry lures from mangrove area at Batan Bay during September to December 1977.

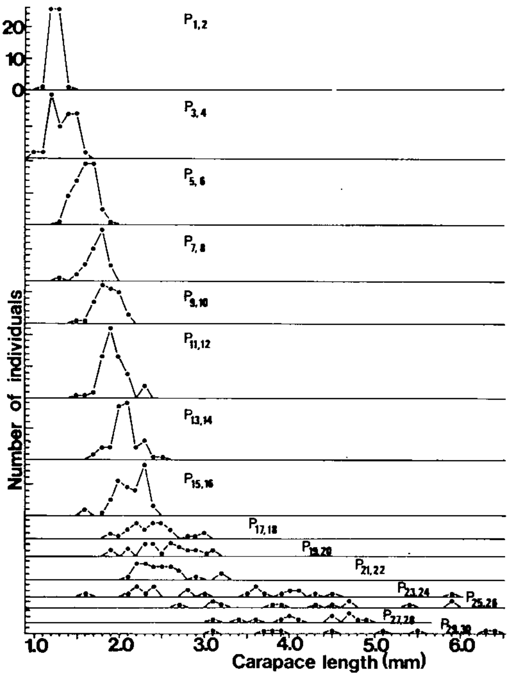

Fig. 75. Size distribution of early postlarval *P. monodon* every two days under laboratory conditions. Numbers depict the day after molted into the first postlarval stage.

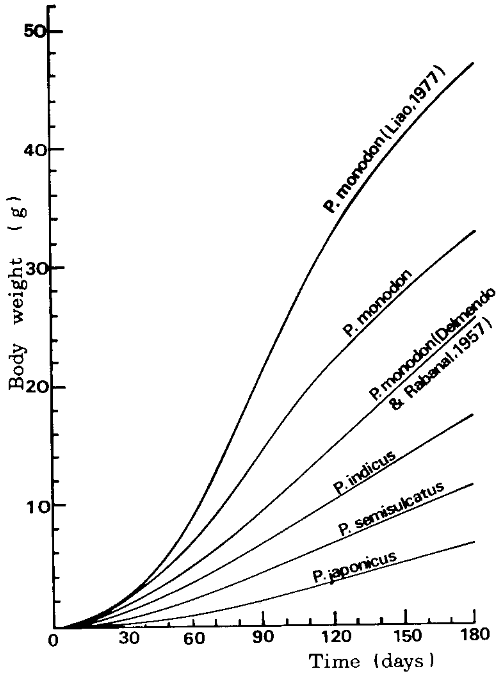

Fig. 76. Growth curves of *P. monodon* and other *Penaeus* spp. reared in brackish prawn ponds, from September 1979 to March 1980.

IX-2. Growth of other *Penaeus* spp.

The result of various prawn rearing experiments in earthen ponds are shown in Fig. 76. Among three species, viz. *P. indicus, P. semisulcatus* and *P. japonicus,* using wild postlarvae, *P. indicus* showed the highest growth representing about 18 g in body weight six months after stocking. On the other hand, the growth of *P. semisulcatus* and *P. japonicus* were low, accounting for about 11 and 7 g, respectively. A few specimens of *P. merguiensis* and *P. latisulcatus* were also found, and the former represented the growth between those of *P. indicus* and *P. semisulcatus,* and the latter similar to *P. japonicus.*

On the basis of these results, it is recommended to collect wild fry of *P. indicus* as well as *P. merguiensis* and to culture them in the ponds.

IX-3. Longevity of *P. monodon*

Based on the data from pond rearing experiments and size composition of the wild specimens, the longevity of *P. monodon* is arbitrarily estimated to be about one and half years for males and about two years for females as mentioned earlier. The higher female to male ratio of 1.5 in offshore water compared to 1.0 in the nursery area could be the result of the greater longevity of the female. However, the life span of each sex is somewhat hypothetical as mentioned earlier. Further detailed experiments on this matter may provide more concrete conclusions.

It is worthy of further study whether it is feasible to undertake monosex culture of females and what economic merit it has, since the females always grow faster than the males.

X. MIGRATION

X-1. Inshore migration

A. Drift card experiment

Temple and Fischer (1965) stated the importance of water currents in the survival of planktonic penaeids. Distribution of larvae depends much on wind-induced surface currents (Subrahmanyam, 1971). Interview with local fry collectors at Batan area pointed out the greater abundance of postlarvae during the prevailing northeast monsoon "Amihan" mostly from November to January.

Numbered, self addressed and stamped drift cards (90 x 155 mm) were used. Each was enclosed in a water tight plastic polyethylene bag with styrofoam float and steel ballast. The instructions to finders were written both in English and Pilipino. With ballast and float, the card was suspended vertically in the water so that its movements depended primarily on the current of the uppermost 20 cm of the surface seawater. Three areas in northern Panay Island were chosen as releasing sites (Fig. 77). Releasing dates were November 1, 3 and 5, 1978 off Pilar Bay, Roxas City and Sapian Bay, respectively.

Result and discussion

The result shows that 92 out of 138 cards (66.7 %) were recovered, however, eight cards did not have accurate entry of recovery date and one card had a defaced serial number. Of the 38 cards released at Pilar Bay, 17 (44.7 %) were recovered from five different areas as follows: Panay (26 %), Pilar, Pres. Roxas and Carles (5 %each) and Pontevedra (3 %). Of the 50 cards released off Roxas City, 43 (86 %) were recovered in two areas, Batan (66 %) and Sapian (20 %). Of the 50 cards released off Sapian Bay, 31 (62 %) were recovered in three areas, New Washington (2 %), Batan (48 %) and Sapian (12 %). Most of the cards reached shore within 10 days.

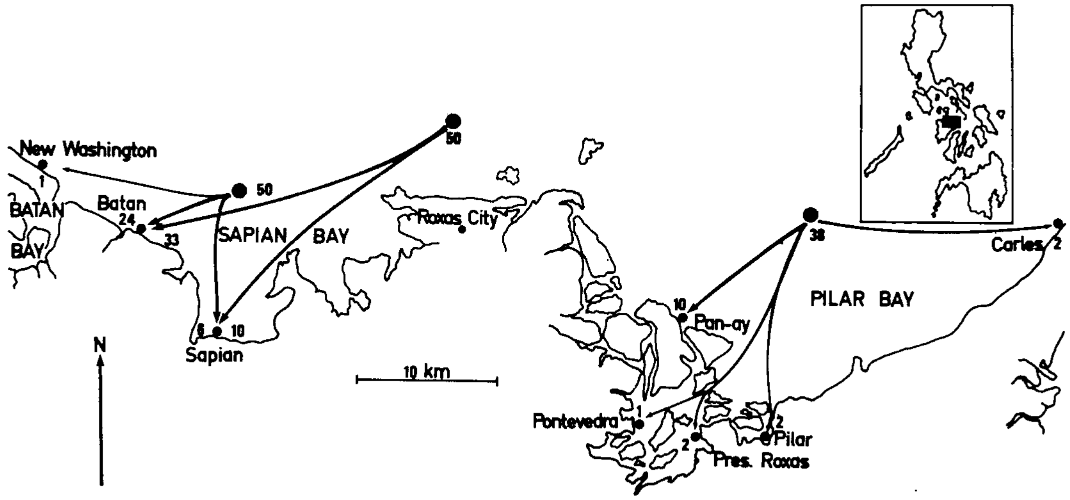

Fig. 77. Drift card release sites and recovery areas off northern Panay Island showing the number of cards released and recovered.

Based on the experimental data, the velocity of wind-induced current varied from 1.3 to 7 km/day in a straight line. Although the present findings do not give a clear answer to the mechanism of water movements which may contribute to the transport of penaeids of larval and postlarval stages to the shoreline, if the spawning occurs in the release site at Pilar Bay and its vicinity, and the sea condition is similar to that during the survey period, the larval stages may be able to reach the Sapian and/or Batan area since the duration of the larval stages is 10 days (Motoh, 1979).

B. Seasonal abundance of postlarval *Penaeus*

The survey was conducted at the shore waters of Villa, from June 1977 to December 1979. Water temperature and salinity fluctuated from 26.6 to 31.0 °C, and 28.5 to 35.5 °/oo, respectively. The organisms most regularly collected in the samples included penaeid postlarvae and juveniles; adult *Acetes* and *Lucifer;* anomuran, macruran and brachyuran larvae; amphipods; copepods; nematodes; ctenophores; pteropods; and fish eggs and larvae, in addition to numerous organic debris.

In general, it was observed that after stormy weather and heavy rain which caused turbid water, the postlarvae were caught in greater numbers. On the other hand, the postlarval catch was poor when diatom, dinoflagellata or filamentous algae were abundant.

The postlarval *Penaeus* consisting of *P. monodon, P. semisulcatus, P. merguiensis* group and *P. japonicus* group were present all the year round with two peak seasons a year, viz. June-July and October-November. However, for any individual species or group the seasonal distribution is quite varied.

P. monodon:

Judging from Fig. 78, there are two peak occurrences of this species in a year, viz. July-August and November-December. However, in comparing three years data, the peak timing was quite varied. Of the four commercially important species or groups of postlarval *Penaeus, P. monodon* is the least abundant accounting for 5.5 % on average of the total postlarvae caught, although it is present all the year round.

P. semisulcatus:

The postlarvae were relatively few in number amounting to 10.8 % next to *P. monodon,* although also appearing throughout the year. Two peak seasons were observed viz. February-March and November-December, with yearly variations.

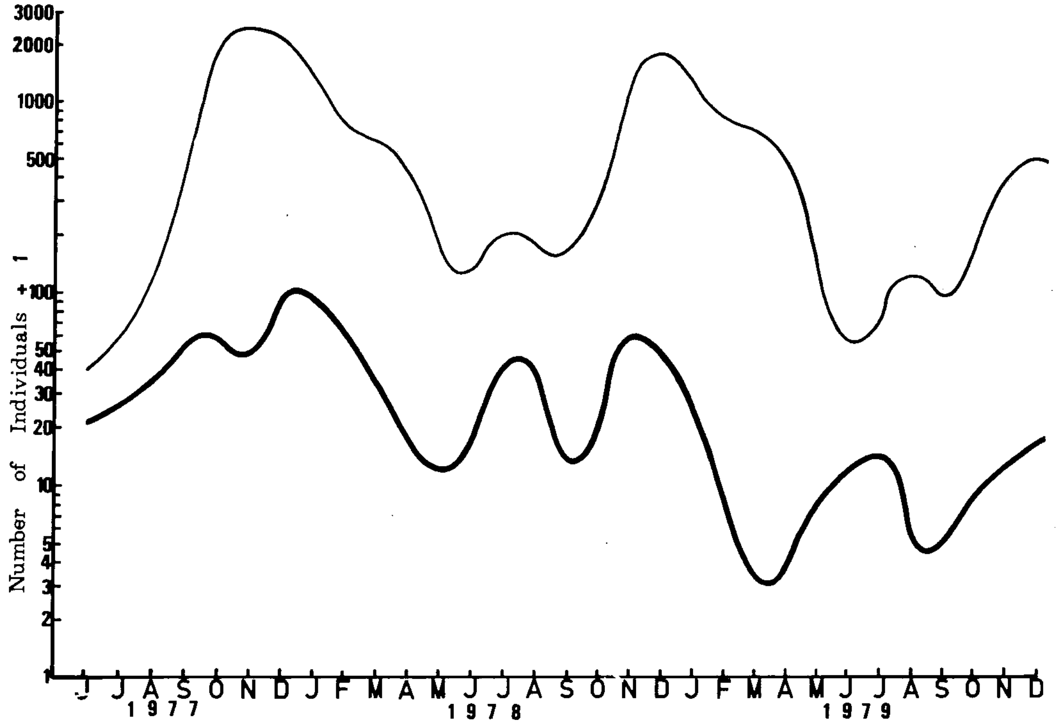

Fig. 78. Seasonal occurrence of postlarval *Penaeus* collected with a triangular net at the shore waters of Villa.

P. merguiensis group:

The postlarvae were always the most dominant species accounting for 65.1 % on average of the total postlarvae caught. It was sometimes observed that the postlarvae suddenly appeared in the shore waters in great numbers but could rapidly disappear, viz. October, 1977, and June, 1978. There could be two peak seasons in a year, viz. June-July and October-November.

P. japonicus group:

This group was second to the *P. merguiensis* group in abundance accounting for 18.6 % of the total postlarvae. There might be two peak seasons viz March-April and September-November.

Discussion

It is highly recommended that fry collectors and fishpond cultivators should utilize postlarvae of the *P. merguiensis* group, in addition to postlarval *P. monodon,* for cultivation in brackishwater ponds, as they are abundant, amounting to 65.1 % of the total postlarvae and have good tolerance of high and low salinity with relatively rapid growth in captivity. Similarly, the postlarvae of *P. japonicus* group might also be available for cultivation.

In conclusion it is suggested that the spawning of all *Penaeus,* which might precede the appearance of fry by about one month, takes place all the year round in the Philippines. Furthermore, each species or group has two peak occurrences in a year. Thus, the peak spawning seasons for species or groups might be estimated as follows: June-July and October-November for *P. monodon,* January-February, and October-November for *P. semisulcatus,* May-June and September-November for *P. merguiensis* group, and February-March and August-September for *P. japonicus* group. This finding is consonant with the spawner occurrences ("VII-3").

C. Size distribution of postlarval *Penaeus* at shore waters

The carapace length distributions of four groups of postlarval *Penaeus* are shown in Fig. 79. *P. monodon* represented the largest size with a modal carapace length of 2.6 mm followed by *P. japonicus* group with a modal carapace length of 2.0 mm. On the other hand, *P. semisulcatus* as well as *P. merguiensis* group showed the smallest modal carapace length of 1.8 mm (Fig. 79). In the case of *P. monodon,* the modal carapace length was almost constant, although from April to June it was smaller (Fig. 80).

There was no size difference of postlarval *P. monodon* between day and night catches (Fig. 81).

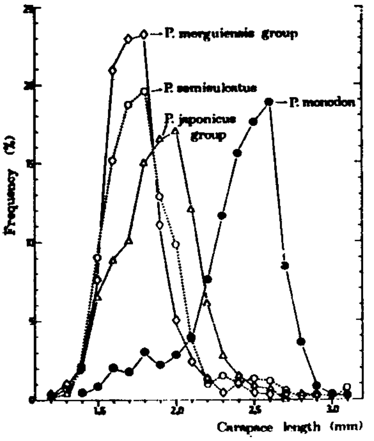

Fig. 79. Size distribution of postlarval *Penaeus* appearing at the shore waters of Villa and Tigbauan, from 1977 to 1979.

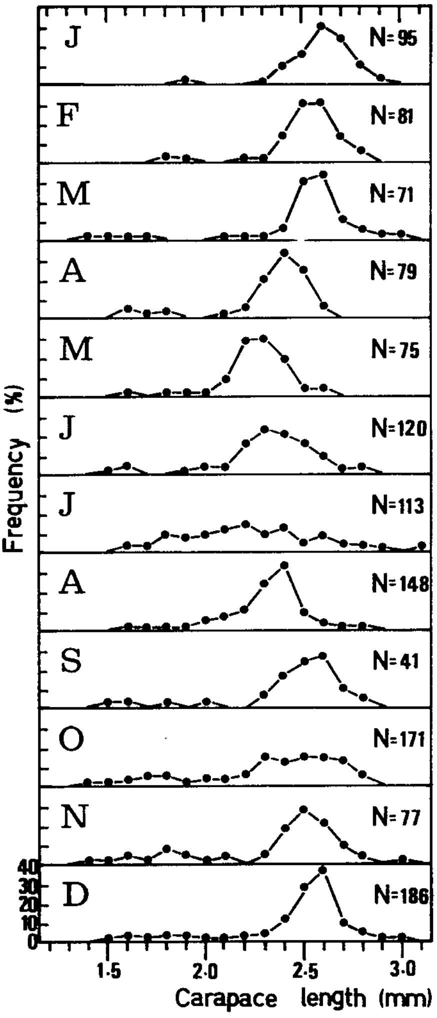

Fig. 80. Monthly size distribution of postlarval *P. monodon* appearing at the shore waters of Tigbauan, from 1976 to 1979.

The similarity of mean carapace length of postlarval *Penaeus* from month to month suggests that a significant growth does not occur in the shore waters and that the area does not play an important role as a nursery ground. In other words, it might be a transitional place for the postlarvae on their way to the nursery ground located in brackish-waters.

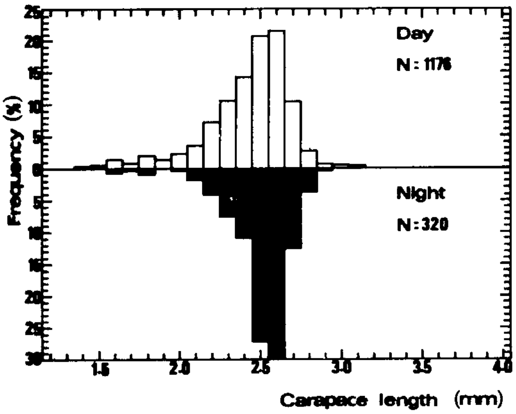

Fig. 81. Size distribution of postlarval *P. monodon* caught at the shore waters of Villa and Tigbauan, from 1977 to 1979. Catching effort per day or night differs.

D. Size distribution of postlarval *P. monodon* in mangrove area

The postlarval *P. monodon* were collected with fry lures made of grasses in a mangrove area (interior portion of Batan Bay), from March 1977 to December 1979. The majority showed a carapace length of 2.6 – 2.8 mm, while some were up to 14 mm CL (Fig. 82).

The seasonal fluctuations of carapace length might be negligible owing to similar modal carapace length of about 2.3 – 2.8 mm, although those during March and April were larger which is probably due to the small size of the sample (less than 70 pieces each month).

The wide carapace length range shows that the mangrove area is important as a nursery ground indicating considerable growth, unlike offshore as well as inshore waters (Fig. 82, 83, 84).

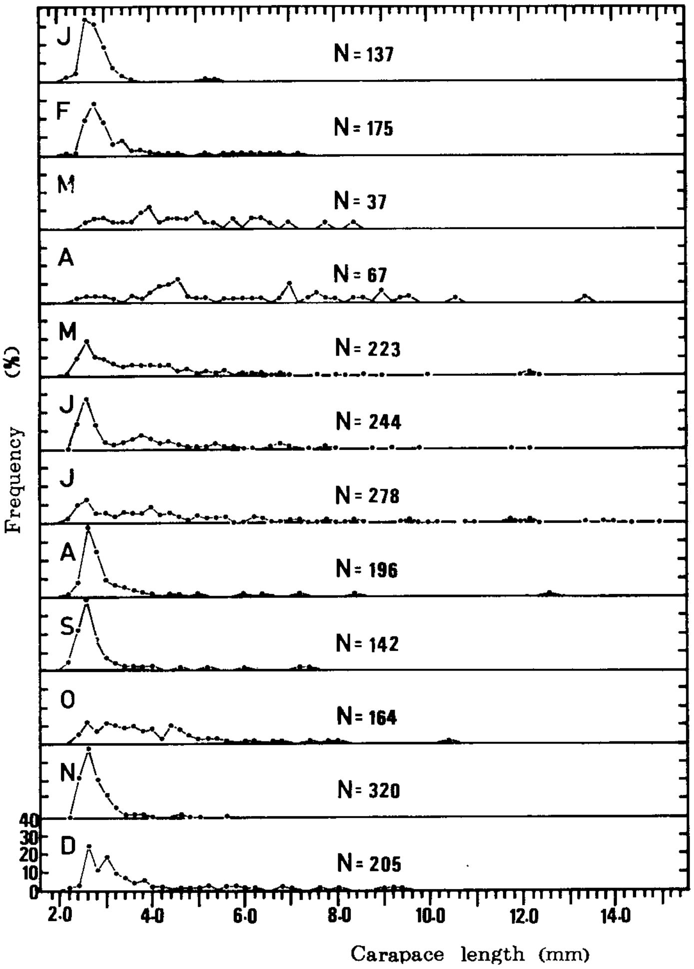

Fig. 82. Monthly size distribution of postlarval *P. monodon* collected with fry lures at the interior portion of Batan Bay, from 1977 to 1979.

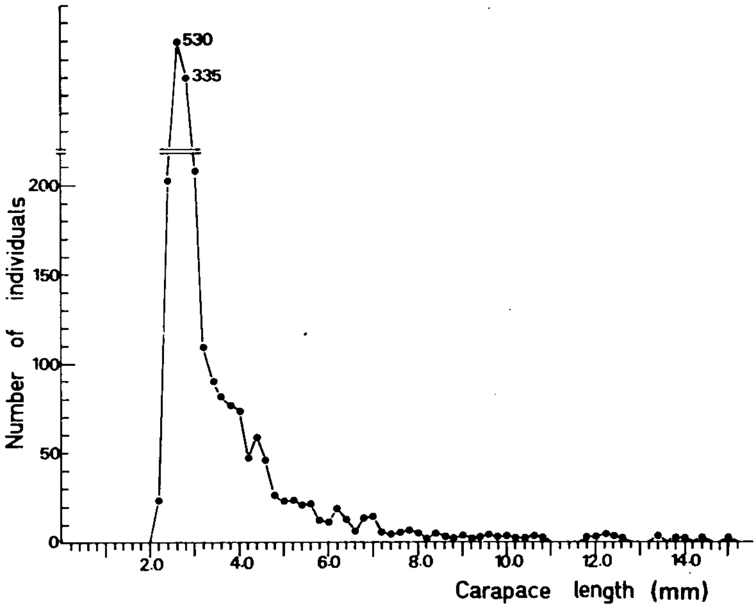

Fig. 83. Size distribution of postlarval *P. monodon* collected with fry lures at the interior portion of Batan Bay, from 1977 to 1979.

E. Local (and seasonal) occurrences of postlarval *P. monodon*

Seasonal occurrence of the postlarval *P. monodon* varies from place to place in the country. In general, there are one or two peak occurrences a year in accordance with the prevailing monsoon. Based mainly on hearsay evidence from local collectors, the local and seasonal occurrences are shown in Table 11 and Fig. 85. In fact, the seasonal occurrence seems to depend primarily on the prevailing monsoon and secondarily on the geographical as well as

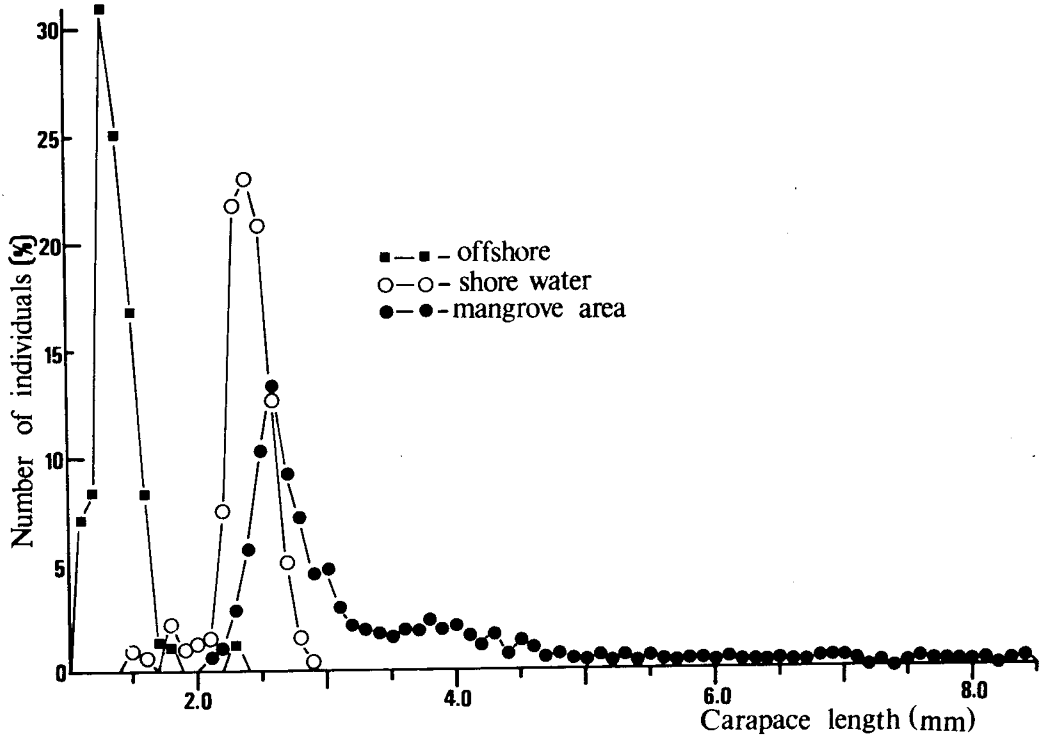

Fig. 84. Size distribution of postlarval *P. monodon* from offshore (■), shore water (o), and estuarine area (●), from 1977 to 1979.

Table 11. **Local and seasonal occurrences of** *P. monodon* **fry, based on hearsay evidences from local fry collectors in the Philippines.**

No.*	Place	Collection period	Peak season
	LUZON		
1	Dalahican	Southwest monsoon	August
2	Atimonan	Northwest monsoon	February
3	Calauag	Year round	Northeast monsoon (February to June except March and April)
	VISAYAS		
4	Batan	Year round	November to February
5	Barotac Nuevo	June to October	August
6	Villa, Tigbauan	May to December	October to November
7	Bolanon, Danao	March to September	May to June
8	Tabao, Caingin	Northwest (December to February) & Southwest (June to November)	August-October
9	Aquisan	Year round	November
10	Bocana, Tabla	July to December	August to September, November
11	Sipalay	March to June, October to December	June, November
12	Malabugas	April to December	May to June
13	Polo	March to June, October-December	June, November
	MINDANAO		
14	Dapitan	Year round	September to October
15	Dipolog	Year round	September to November
16	Ozamis	Northeast & Southwest monsoon	July, November to December
17	Zamboanga	September-November	–
18	Tagum	Northeast & Southwest monsoon	April to May, October to November
19	Matina, Aplaya	Northeast monsoon	April to May

* Corresponds in Fig. 85.

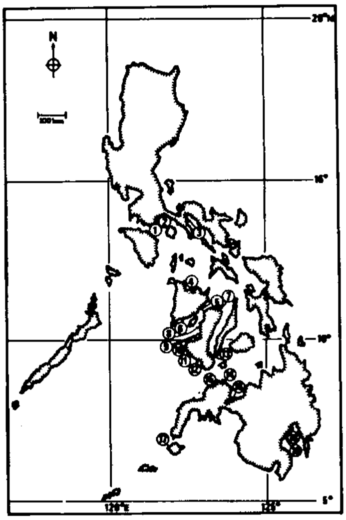

Fig. 85. Map showing the fry collecting areas for commercial purposes in the Philippines (See Table 11 for detailed explanation).

socio-economic conditions. For instance, when the place is protected by a small peninsula or islet, the season might be delayed or advanced in time. Furthermore, the fry collecting activity (catching effort) is sometimes dependent on the demand for fry in the vicinity. Prawn culturists usually do not buy sugpo fry immediately prior to a dry season. They usually stock milkfish fry instead of sugpo fry, because the former has a greater tolerance to higher salinity than the latter.

The fry seem to be in part carried by wind currents generated by the northeast and/or southeast monsoon.

F. Diel occurrence of postlarval *P. monodon*

The ecology of the postlarval *P. monodon* with regard to its seasonal, local and diel abundance has been fragmentarily documented in other countries (Subrahmanyam and Rao, 1969 ; Subrahmanyam and Ganapati, 1971 ; Noor-Hamic, 1976; de Jesus and Deanon, 1978), so far as the present author is aware.

The purpose of this investigation was to measure diel fluctuations in the catch of postlarval *P. monodon* in relation to the tidal cycle, water temperature and salinity. Such information may be advantageous in terms of fry collection for commercial purposes and may possibly result in increased production of prawns cultured in brackishwater fishponds.

From February 23 to 27, 1979, samplings of postlarval *Penaeus* were made with a triangular push net every two hours over a 96-hour period. The net which was operated by one person had a mouth of about 3.2 m wide and was made of synthetic net of 0.9 mm mesh size. The sampling site was over a muddy sand or fine gravel area in water varying 90 to 120 cm deep adjacent to the shoreline at Tigbauan.

Air temperature, water temperature and tidal height varied from 22.3 to 33.4°C, 26.2 to 29.9°C, and 0 to 174 cm, respectively. Salinity was almost constant showing a slight variation (from 33.8 to 34.5 ‰) which might be attributed to lack of rainfall during the survey period and the absence of a large river discharging into the adjacent waters.

Result and Discussion

Four species or groups were identified among the 16,883 individual postlarvae of the genus *Penaeus* captured during the study. From those identified, 6,940 (41.1 %) were considered to be *P. semisulcatus;* 6,648 (39.4 %) to be *P. merguiensis* group; 2,617 (16.5 %) to be *P. japonicus* group; and the smallest number, 678 (4.0 %) to be *P. monodon.*

Analysis of the frequency distribution of the numbers of dorsal rostral spine of postlarval *P. monodon* showed a peak at 5 spines. The most frequent carapace length was 2.6 mm being the largest among the four species or groups of *Penaeus* collected. There was no significant difference in carapace length and number of dorsal rostral spine between day and night catches of *P. monodon* postlarvae (Fig. 86).

Major peak catches of postlarval *P. monodon* were taken at night, between the hours of 1800 and 2000, 2 to 4 hours before high water and when the water temperature was declining or about to decline in each of the four tidal cycles (Fig. 87). Minor peak catches occurred during the day, between 0800 and 1200, when the water temperature was rising, 0 to 4 hours before lower high water. Another peak was observed at 0400 during the ebb tide, water temperature was at its lowest on February 25. In such a shallow area, water temperature can be decreased at night with incoming tidal currents. However, there was a significant positive correlation ($r = 0.337$) between tide elevation and water temperature ($t = 2.8376$, $df = 47$, $P<0.05$).

There was no effect of moon light since the survey was conducted during the new moon period.

No significant difference in the catch of postlarval *P. monodon* was found between eastward and westward operation of the net, as almost the same numbers of individuals were collected with each operation (353 from eastward and 356 from westward operation, out of 49 times each) ($r = 0.147$, $P < 0.70$).

Tabb *et al.* (1962), using a plankton net operated from a stationary position in Florida, reported that catches of postlarval *P. duorarum* were greater at night and during flood tide than during the day and ebb tide, while Eldred *et al.* (1965) noted the nocturnal rhythm of postlarval *P. duorarum* is not so persistent in Tampa Bay, U.S.A.

Baxter (1964) observed in Texas that catches of postlarvae (probably *P. aztecus)* were higher at night (from 2000 to 0600 hours) than during the day. St. Amant *et al.* (1966) showed in Barataria Bay, Louisiana that catches of postlarvae, probably, *P. setiferus* and *P. aztecus* were greater during the incoming tide. Caillouet, Jr. *et al.* (1968) using the Renfro Beam Trawl in a tidal flat in Louisiana, reported that peak catches of postlarval *P. setiferus* per tow occurred at night, 2 to 4 hours after high water and at the lowest water temperature. Caillouet, Jr. *et al.* (1970) observed in a tidal flat in the Gulf of Mexico, that the afternoon peaks of postlarval *P. aztecus* were associated with increasing water temperature, whereas the peaks after dark occurred as water temperature decreased. They further observed that there was no significant difference between the frequency distributions of the day and night catches.

William and Doubler (1968) suggested that postlarval *P. aztecus* and *P. setiferus* in surface plankton are more abundant at night than during the day and the night has a greater influence on postlarval *P. setiferus* than on postlarval *P. aztecus* in North Carolina estuary. They suggested further that postlarval *P. setiferus* are more abundant on dark nights than moonlit nights.

Caillouet, Jr. *et al.* (1970) mentioned that either the movement of the postlarvae occurred mostly on incoming as well as partially on outgoing tides or the high water temperature in the afternoon may have stimulated actively in the postlarvae in the shallow water.

In the present study, there is a significant relationship between postlarval occurrence and tide elevation. The major peaks in catch at night (1800 to 2000) were associated with rising tide and decreasing water temperature, whereas the minor peaks in catch during daytime accompanied rising tide and increasing water temperature. These results suggest that the postlarval *P. monodon* are carried shoreward mostly at night by incoming tidal currents and reach a peak occurrence 2 to 4 hours before high water. This phenomenon for *P. monodon* is principally in agreement with the observations made by several workers mentioned above.

However, the major peaks of *P. setiferus* occurred at night 2 to 4 hours after high water (Caillouet, Jr. *et al.*, 1968), while major peaks of *P. monodon* were at night 2 to 4 hours before high water. This discrepancy might be attributed to the geographic and oceanographic conditions in the sampling area, in addition to the characteristics of the different species. A further comparative study on this matter is desirable.

It seems from Fig. 87 that the night peak occurrence at 1800 on February 24 is relatively lower than other peaks (1800 hours on February 23, 2000 hours on February 25, 2000 hours on February 26), while an additional peak occurred at 0400 hours on February 25. During the sampling period on February 24 to 25, there was a moderate offshore wind. This result suggests that the wind might have partially scattered the population of postlarval *P. monodon* resulting in an abnormal peak occurrence. However, no final interpretation of the result has yet been possible.

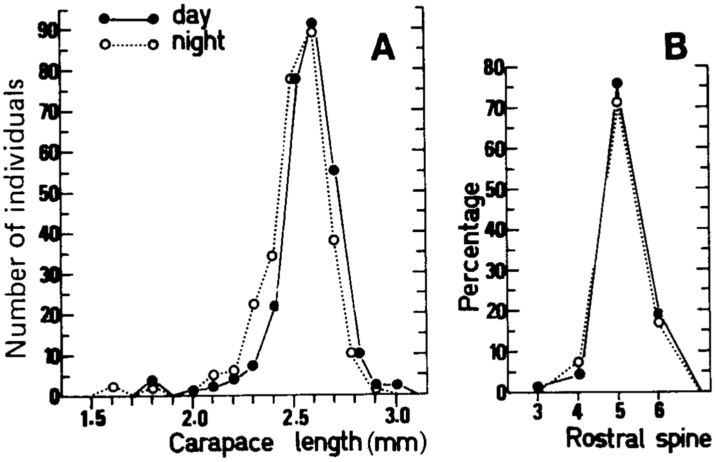

Fig. 86. Size distribution of postlarval *P. monodon* caught during a 96-hour collection at the shore waters of Tigbauan, 1979. A, carapace length distribution; B, number of upper rostral spine, by day and night catch.

Caillouet, Jr. *et al.* (1970) observed major peak occurrences of postlarval *P. aztecus* after severe squalls. During the present survey no rainfall was observed resulting in fairly constant water salinity. Thus any relationships between postlarval occurrence and salinity fluctuations would not be apparent during the present study owing to the small salinity range recorded.

Judging from Fig. 87, the time of the major night peak was delayed gradually from 1800 to 2000 in accordance with the progression of the time of highest tide. The phenomenon means the movement of postlarval *P. monodon* is directly associated with the tidal movement.

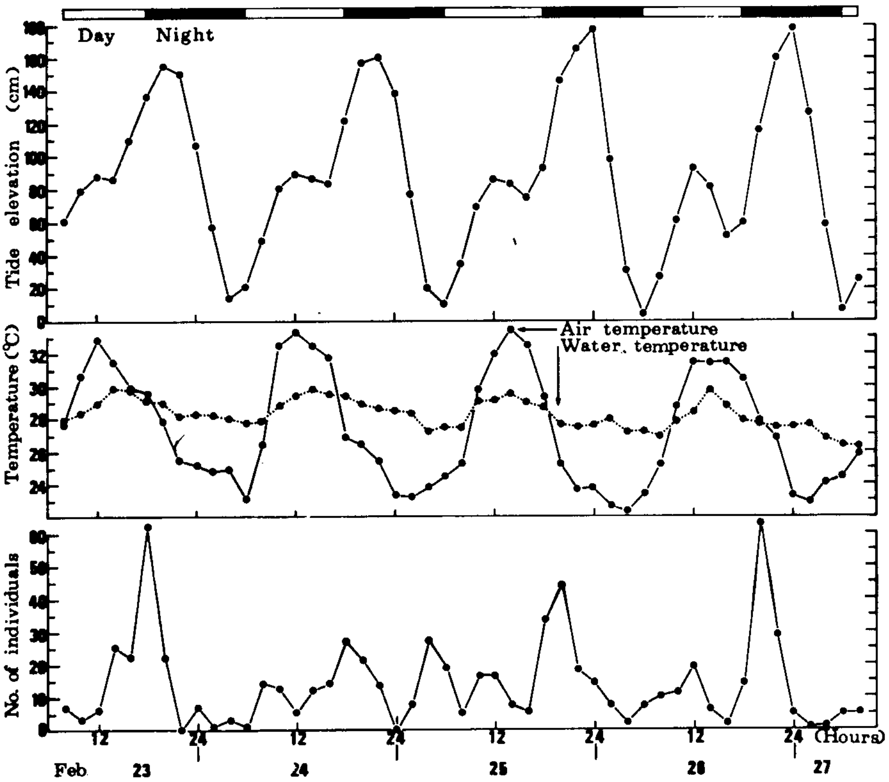

Fig. 87. Fluctuations in tide (upper), air and water temperatures (middle), and catch of postlarval *P. monodon* (lower) at 2 hours intervals during a 96-hour period at the shore waters of Tigbauan, 1979.

G. Relation to moon phase

From November 20, 1978, to February 20, 1979, daily postlarval samplings were conducted in the morning at shore waters of Tigbauan.

The results are shown in Fig. 88. In general, the postlarvae are abundant after new or full moon. According to the data of tidal conditions (Fig. 89), the greater tidal fluctuations usually occur after new or full moon. Therefore, it seems that the postlarval *P. monodon* are mostly transported with incoming tidal currents.

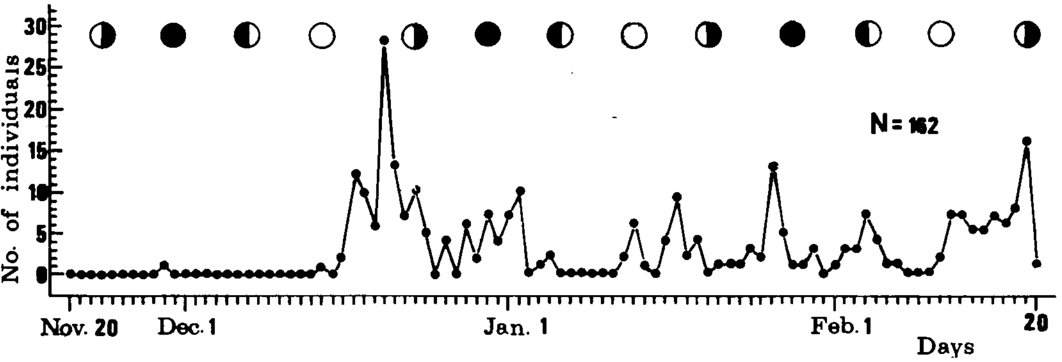

Fig. 88. Daily fluctuations of postlarval *P. monodon* collected with a triangular net at the shore waters of Tigbauan, Iloilo, from 1978 to 1979.

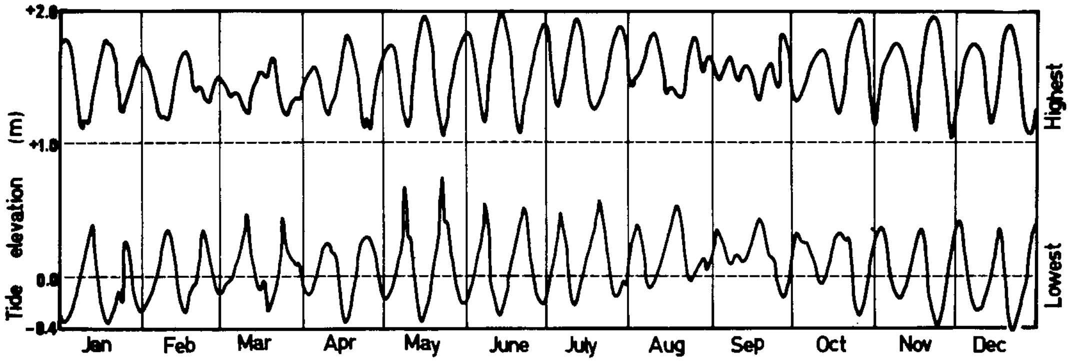

Fig. 89. Daily tidal fluctuations in 1976, based on Iloilo Port, Philippines.

H. Temperature and salinity tolerance of postlarva

As has been studied earlier (Hughes, 1966; Young and Carpenters, 1977; Staples, 1979) not only the giant tiger prawn but also other penaeid prawns spend their postlarval and juvenile stages in shallow brackishwaters as nursery grounds where physico-chemical conditions such as salinity and temperature vary considerably.

The main purpose of this part was to evaluate the water temperature and salinity tolerance of the megalopa and juvenile *P. monodon* for assessing mortality caused by extreme variations of this parameters in nursery area under natural conditions.

The specimens of *P. monodon* used for the present study consisted of three groups: megalopa (P_{2-8}*, 1.6 to 2.0 mm CL), early juvenile (2.3 to 2.7 mm CL), and juvenile (4.9 to 7.5 mm CL). The first group was reared in the hatchery of SEAFDEC, the second caught with a triangular net along the shore waters of Villa,

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*Number depicts the days after molt into the first megalopa or postlarval stage.

and the third with fry lures made of grass or twigs in the brackish river of Villa. Other postlarval *Penaeus* spp. were caught with a triangular net along the shore waters.

The animals, for convenience here sometimes collectively called postlarvae, were gradually acclimated to the desired salinity or temperature before starting each experiment.

For the experiments on temperature tolerance, groups of 10 postlarvae were placed in glass aquaria containing 5 *l* of continuously aerated seawater (salinity approximately 32 ‰ at start). Five such aquaria, containing a total of 50 animals, were held in one wooden tank containing about 100 *l* which was equipped with an electric heater or a refrigerator for temperature control. The rates of lowering and rising temperatures were about 2 °C per hour, while at the critical periods the rates were reduced to 0.5 °C.

For the experiments on salinity tolerance, groups of 10 postlarvae were placed in glass aquaria containing 5 *l* of continuously aerated seawater with ambient temperature varying from 26 to 31 °C at start. The changing rate of salinity was 4 to 5 ‰ per day, while during the critical periods it was reduced to 1 or 2 ‰ per day. Lighting was ambient daylight.

Experimental animals were fed on live young or adult brine shrimp (*Artemia*) so as to provide a constant supply of food during the experiment. For all experiments, a similar number of prawns were held at constant temperature or salinity as a control.

Stoppage of the heartbeat was taken as the criterion for the death point of the animal.

The experiment was conducted intermittently using different batches of animals during the period from February 1979 to March 1980.

Result

i) P. monodon

Low temperature

The first mortality occurred when the temperature was lowered to about 10 °C, with slightly higher survival for megalopa, while early juvenile showed lower survival. LT_{50} value (10 hours) was found at 7 to 9 °C among all groups. Acute mortality was shown at between 6 and 8 °C at almost the same time by all groups as shown in Fig. 90. One hundred percent mortality occurred at 7 °C for the early juvenile, at 6.5 °C for the juveniles, and 4.8 °C for the megalopa.

High temperature

Up to at about 39 °C, virtually no mortality was found and mean survival was 98 % . Once the temperature rose to 41 °C, heavy mortality occurred and all were dead before the temperature had reached 42 °C as shown in Fig. 90. There seems to be no significant difference among the three groups in terms of survival.

Low salinity

In the case of megalopa, when the salinity was lowered to about 28 ‰ first mortality was observed, two out of 50 animals died. As salinity was lowered, the survival gradually became less, however, at 0 °/oo, more than 64 % of the postlarvae survived showing a great tolerance to the lower salinity.

Of the early juvenile, 92 % survived at 0 °/oo, while the greatest tolerance was shown by the juvenile with 100 % survival at 0 °/oo (Fig. 91).

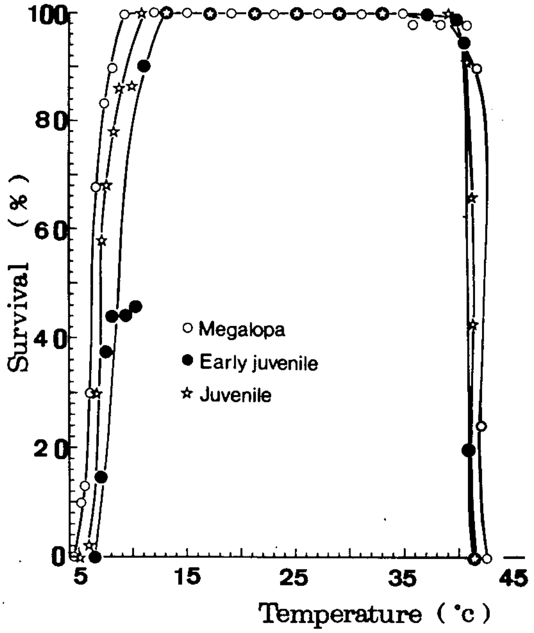


Fig. 90. Temperature tolerance of postlarval *P. monodon* under laboratory conditions.

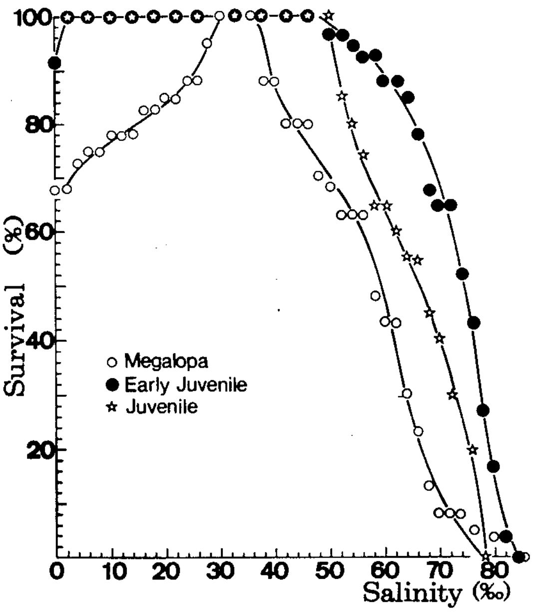


Fig. 91. Salinity tolerance of postlarval *P. monodon* under laboratory conditions.

High salinity

The first mortalities occurred at 38, 50 and 52 °/oo for the megalopa, early juvenile and juvenile, respectively, showing greater tolerance among older stages.

LT_{50} values (24 hours) were 58, 67 and 75 °/oo for megalopa, juvenile and early juvenile, respectively. One hundred percent mortality was caused at 78, 84 and 86 °/oo by the juvenile, early juvenile and megalopa, respectively (Fig. 91).

Hudinaga (1942) reported that the survival range of megalopa (as postlarval) *P. japonicus* was between 7.5 nad 39.3 °C for water temperature, and between 19.0 and 52.0 °/oo for salinity. These ranges are relatively narrower than those shown by *P. monodon* in the present study. This discrepancy might be due to the character of *P. japonicus* which is more or less a temperate species, while *P. monodon* is a tropical one.

In the nursery area, e.g., the interior portion of Batan Bay, the mean monthly water temperature and salinity were observed to fluctuate between 24.3 and 32.4 °C and between 15.0 and 32.3 °/oo for the past three years as mentioned earlier. Considering the wide tolerance of postlarval *P. monodon* to both temperature and salinity, the postlarvae would have no difficulty surviving under these conditions, thus it can be said that mortality caused by the environmental conditions such as temperatures and salinity might be negligible in the nursery ground.

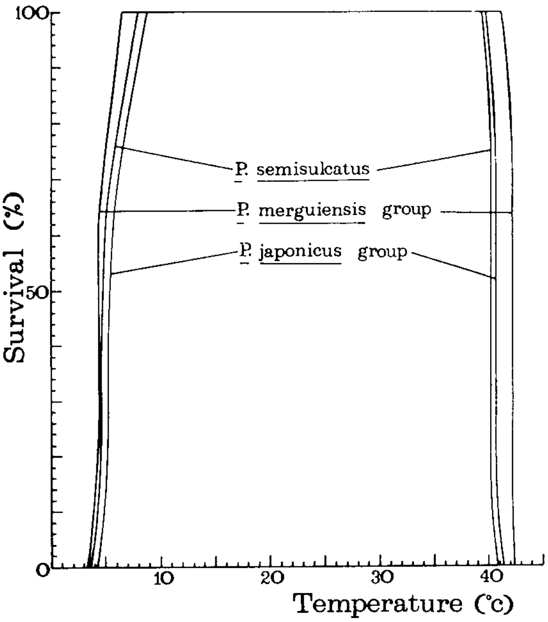


Fig. 92. Temperature tolerance of early juveniles of *Penaeus* spp. under laboratory conditions.

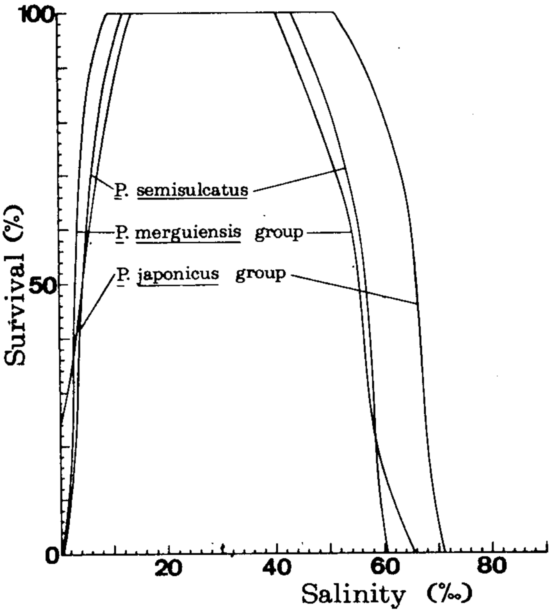


Fig. 93. Salinity tolerances of early juveniles of *Penaeus* spp. under laboratory conditions.

ii) Other *Penaeus* spp.

In the case of temperature tolerance the three groups showed similar tolerance showing about 100 % survival between 9 and 39 °C which is almost the same range as that of *P. monodon*. In salinity tolerance, on the other hand, *P. japonicus* group showed greatest tolerance to higher salinity, showing 100 % survival up to 50 °/oo, while *P. merguiensis* showed the least tolerance. However, at the lower salinity, *P. merguiensis* showed the highest survival, while *P. japonicus* the least (Figs. 92 and 93).

These tolerances both to temperature and salinity ranges are generally not greater than those by *P. monodon.*

I. Fry collecting gear and methods

Observations and description

There are presently 9 kinds of gear in use for collecting sugpo fry (postlarval *P. monodon*) (Table 12).

In rural areas, fry concessionaires use wide-mouthed earthen jars, locally called "kulon" or "palayok", 36 cm in outer diameter (Fig. 94) for holding sugpo fry. Some 2,000 sugpo fry can be stored in the jar when half-filled with approximately 10 *l* of seawater for 2 to 4 days without aeration. The advantage of this native container is that it provides relatively lower water temperature (by about 1.5 °C) due to the porosity of the jar, resulting in evaporation of water from its outer surface. In addition, it is cheap and locally available. Recently many fry concessionaires as well as collectors are using white plastic basins 86 cm in diameter and 15 cm in depth instead of "kulon", as the basin is more durable and makes counting of the blackish brown fry easier against the white background. It is for the same reason that a white plastic cup is used for removing fry from the container instead of a half coconut shell that is dark brown in color.

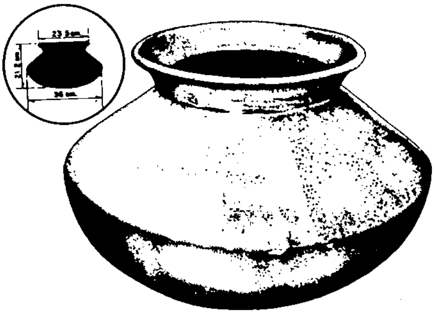


Fig. 94. Wide-mouth earthen jar "kulon" for holding sugpo fry.

A. Stationary gear

1) Fry lure (Fig. 95)

Fry lures locally called "bonbon", "bungot-bungot", "habong", or "pagung-pong", are simple devices made of bundles of twigs, brackishwater grass (*Paspalum vaginatum*), or coconut peduncles. The fry lures are usually set in mangrove creeks or brackishwater rivers where they are protected from strong currents or waves. Each lure is tied to a long line of rattan string or hung on wooden poles at intervals of 1.5 to 2 m and placed near the banks of brackishwater river. Sometimes they are directly set in the shallow area of the brackishwaters. Fry collectors visit the lures during low tide, mostly in the early morning, and place a dipping scoop net, locally called "salap" or "dusdus" beneath each bundle of the lure. The collectors then shake the lure vigorously to remove the clinging sugpo fry into the dip net. The clinging habit of the fry in brackishwater nursery grounds makes this lure effective.

Table 12. Fry (postlarval *P. monodon*) collecting gear used in the Philippines today (local names are enclosed in parentheses).

	Gear	Area operated
A.	Stationary gear	
	1. Fry lure (bonbon, bungot-bungot, habong, pagung-pong, palipi)	Mangrove area, brackishwater river
	2. Fry filter net (tangab)	Shore waters
	3. Capiz patterned filter net	Mouth of brackishwater river
	4. Fry raft (saplad)	Brackishwater river
B.	Mobile gear	
	5. Fry seine (sabay, sagap, sayod, sibut-sibot, suyod)	Shore waters
	6. Triangular net or scissors net (hudhud, sakag)	do
	7. Fry bulldozer or fry dozer (baka-baka, traveller)	do
	8. Fry scare line (surambaw)	do
	9. Scoop net (sibut-sibot, dusdus, salap)	Mangrove area, brackishwater river

2) Fry filter net (Fig. 96)

The fry filter net, locally known as "tangab", is made of main and guide nets and two pieces of wooden or iron sticks. Unlike the mobile gear, this net requires water current accompanied by moderately strong waves.

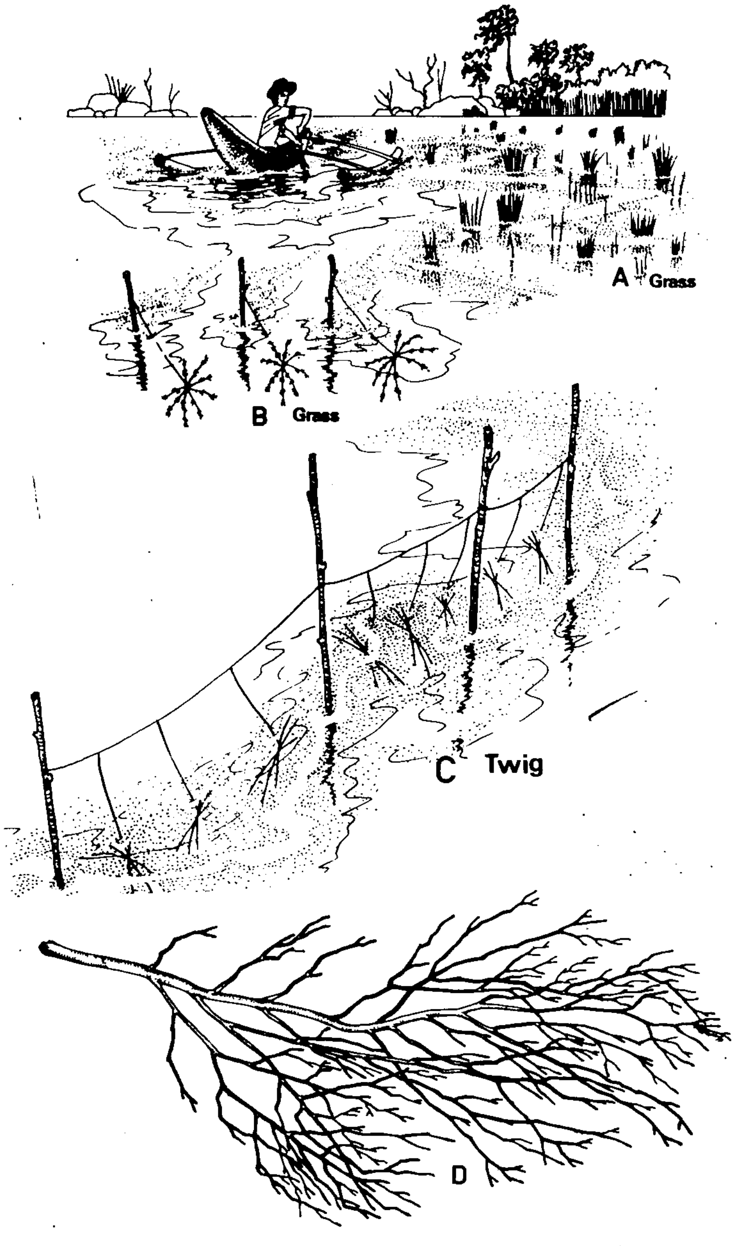


Fig. 95. Fry lures made of grasses (A,B) and twigs (C,D).

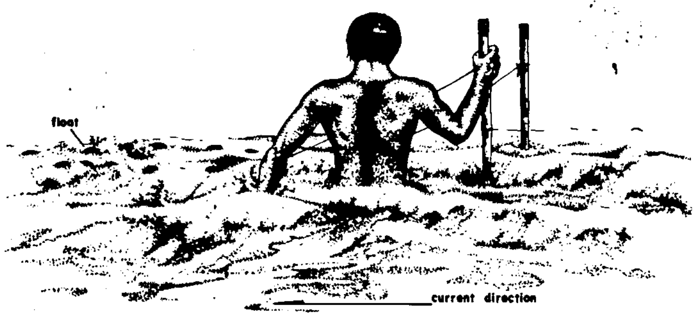


Fig. 96. Operational view of fry filter net.

The gear is usually located near the shore in water up to 2 m deep. Two poles are positioned obliquely to the shoreline against the current. Instead of moving the gear, the fry are carried with the current into the net. From time to time, the fisherman removes the contents of the codend (terminal portion of the net) which contains not only *P. monodon* fry but also many other organisms, and brings them to the shore for sorting. The operator can sometimes collect more than 200 sugpo fry within an hour, particularly during the monsoon season. This gear is adapted to the nature of the sugpo fry when migrating and/or being transported with wind-induced and tidal currents approaching the shore waters, particularly when the water is turbid during flood tide.

3) Capiz patterned fry filter net (Fig. 97)

This stationary gear consists not only ot netting parts but also of a bamboo raft and one small nipa hut. There are some twenty bamboos which serve as a raft and platform for operation. The nipa hut on the raft serves as a resting place for the operator. In the front, bamboo poles holding the guide nets are held far apart.

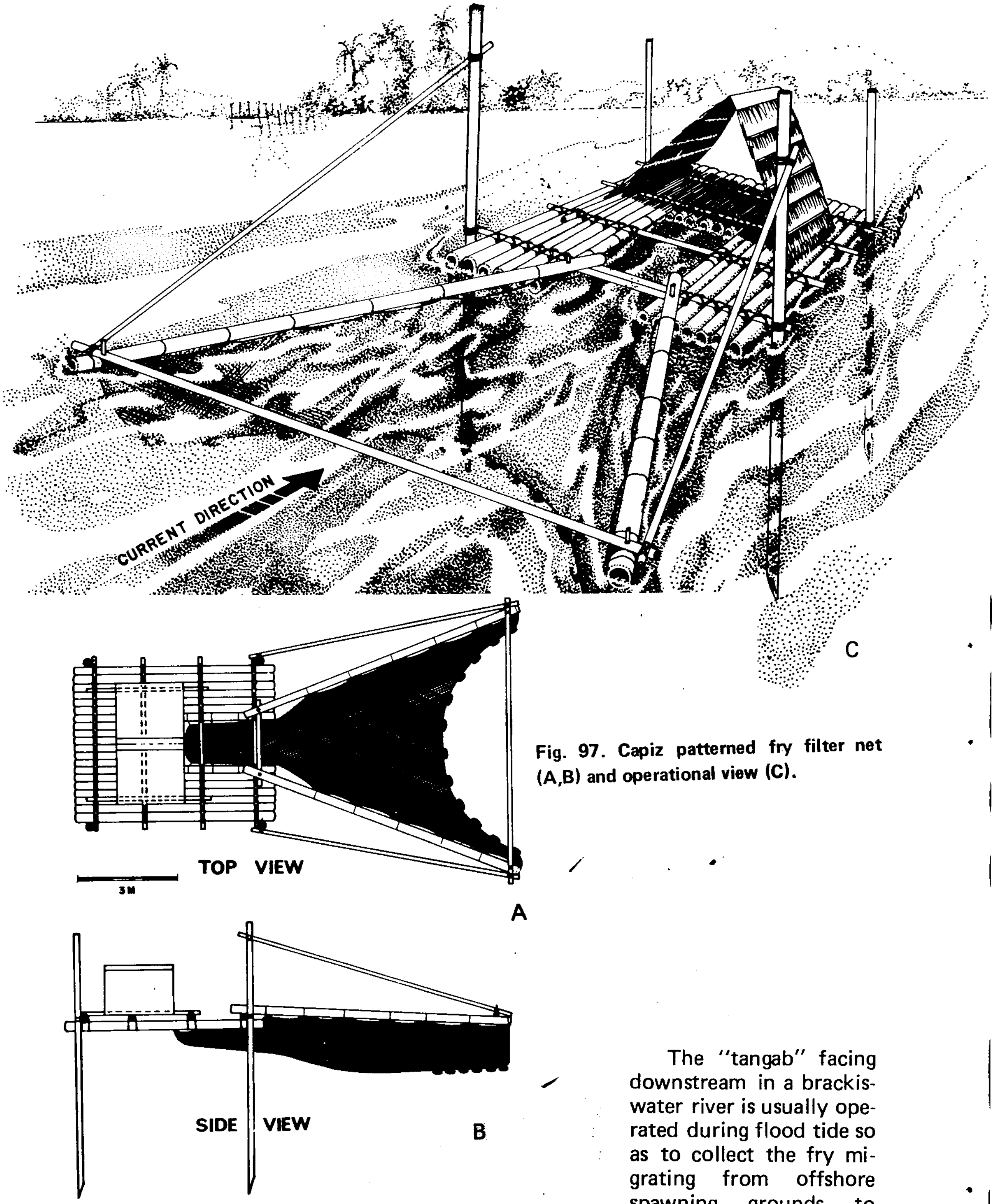


Fig. 97. Capiz patterned fry filter net (A,B) and operational view (C).

The "tangab" facing downstream in a brackiswater river is usually operated during flood tide so as to collect the fry migrating from offshore spawning grounds to brackishwater nursery grounds together with incoming tide. The name "capiz" was derived from Capiz Province, northern Panay Island, Philippines, where the traditional "tangab" was modified.

4) Fry raft (Fig. 98)

The fry raft locally known as "saplad" consists of a long raft made of several pieces of big bamboos made into a guiding net and codend both made of synthetic material.

This gear is principally the same as the "Capiz patterned filter net" and used for collecting fry migrating with incoming tidal currents at or near the mouth of brackishwater rivers.

There are differences between the two, however: i) The fry raft is moored at the river bank, thus the operator can take a rest at home or on land anytime he wants to between harvesting periods, while the "Capiz patterned filter net" is equipped with a nipa hut where the fisherman can rest without going back to land; ii) with the fry raft, the fry are guided by means of the guiding net which has a depth of only about 20 cm without bottom parts except at the collecting portion, while the "Capiz patterned filter net" uses entirely enclosed guiding net forming a semi-circle. During night operation, a kerosene lamp is sometimes used to attract fry as well as for the aid of the collection.

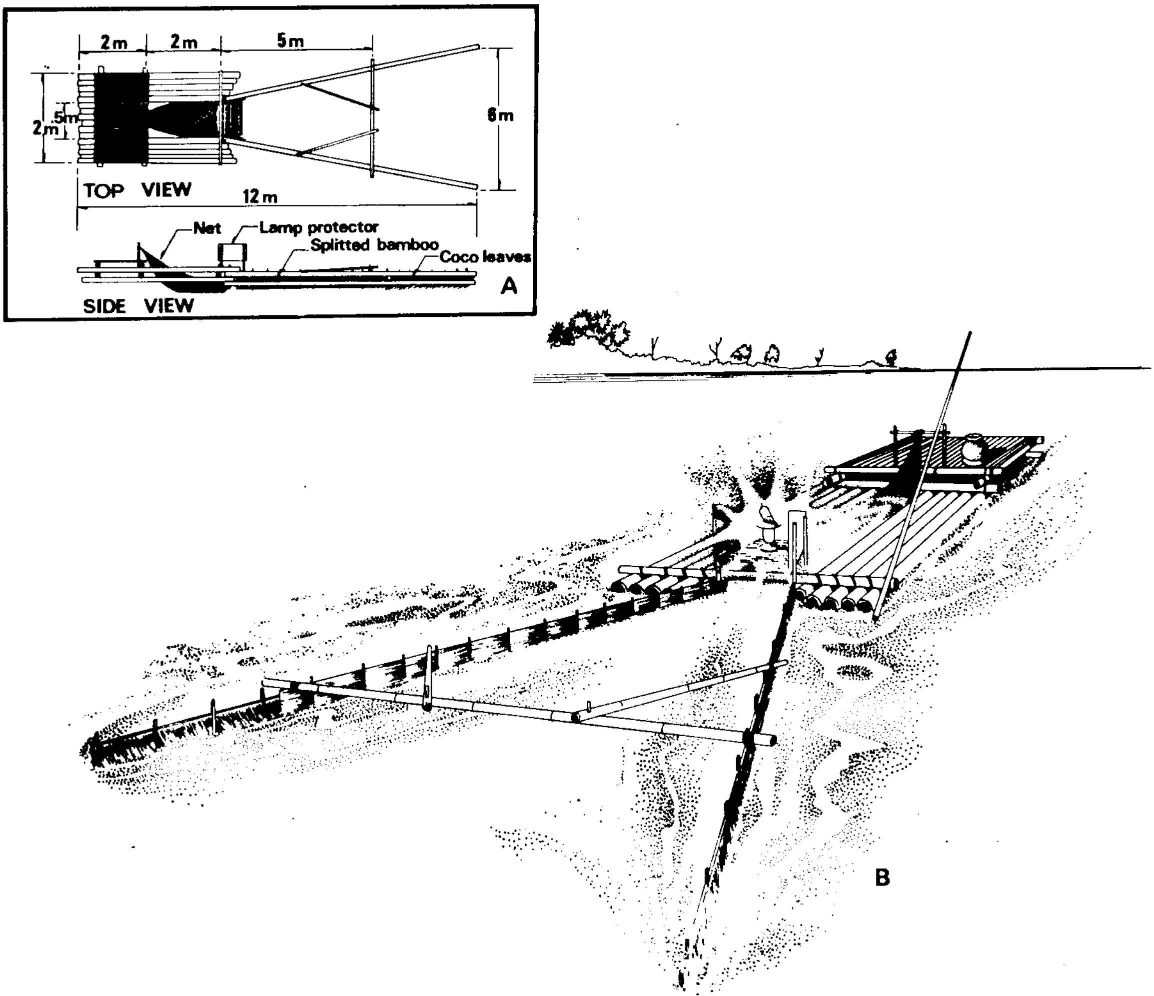


Fig. 98. Fry raft (A) and operational view at night (B).

B. Mobile gear

5) Fry seine (Fig. 99)

The fry seine, locally called "sabay", "sagap", "sayod" or "sibut-sibot" is a kind of small hand net with dimensions of 3 to 6 m long and 1 m wide. The net is made of finely woven abaca cloth or "sinamay". The upper and lower edges are attached to a stout abaca rope for holding. There are neither weights nor floats, so that either cord may serve as the bottom line. However, a modified fry seine with lead weights on one edge and rubber floats on the other. The "sagap" is operated in shore waters up to waist depth, along the sandy beach by two persons holding opposite sides and dragging the net slowly, sometimes bending their waist, parallel to the shore. The upper border of the net is usually kept slightly above the water surface when in operation. The sugpo fry inhabit the shore waters, probably seeking for brackishwater, thus this kind of collecting method is useful, similar to the use of the fry filter net.

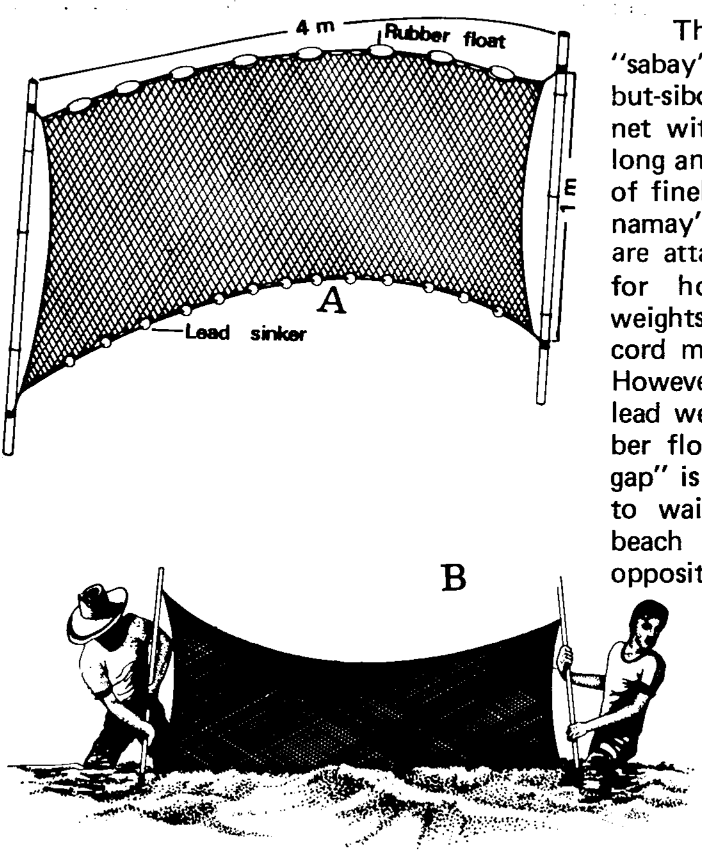


Fig. 99. Fry seine (A) and operational view (B).

6) Triangular or scissors net (Fig. 100)

The triangular net, locally called "sakag" or "hudhud", consists of a flattened conical bag made of fine-meshed (about 0.9 mm) sinamay or salap netting (cloth woven from the fiber of Manila hemp) and two pieces of bamboo poles with a wooden or bamboo shoe at each end. The length of the net is about 5.5 m from the mouth to the codend with the local variations. A wooden nail or peg connects the poles at their intersection and allows them to be worked in a scissors-like manner. The proximal portions from the pivot serve as handles for the operator. A modified gear is equipped with a semicircular wooden plate for pushing

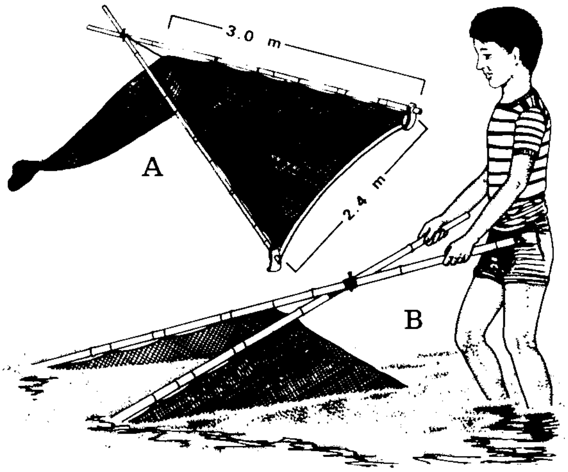


Fig. 100. Triangular net (A) and operational view (B).

against. The distal end of each pole is equipped with a runner or shoe which is adz-shaped and is made of curved wood or the proximal portion of a big bamboo, about 30 cm long.

The triangular sweeping net is operated as a large scoop net by a person wading in waist deep water, parallel with the shoreline.

It is called a triangular or scissors net because it forms a triangle and looks like a pair of scissors.

7) Fry bulldozer or fry dozer (Fig. 101)

The fry bulldozer or fry dozer, locally called "baka-baka" or "traveller", is made of several pieces of bamboo poles serving as frames and floats with sinamay (finely-woven abaca cloth) or synthetic netting and several stone or lead sinkers. It looks triangular or trapezoidal in shape. The dimensions are usually 210 cm wide in front, 76 cm wide at the rear, and 300 cm long. The depth of wing net is up to 15 cm only, while the length sometimes 5 m. The fry dozer, which is a floating type, is operated by one or two persons pushing it, parallel to the sandy shore, although the manner of construction as well as the size varies according to locality. Unlike the sweeping type such a triangular net, this floating gear has relatively poor catching effort, because the prawn fry mostly dwell at or near the bottom. The fry dozer is more efficient for collecting finfish fry like "bangos" (*Chanos chanos).*

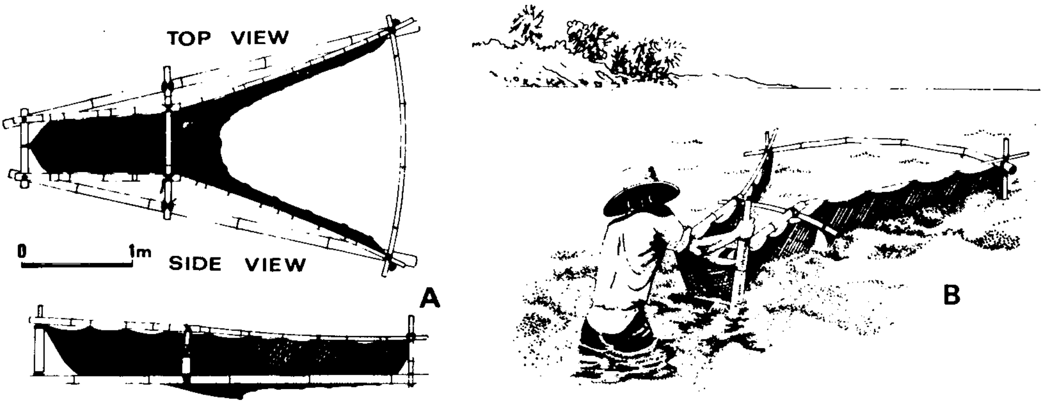


Fig. 101. Fry bulldozer (A) and operational view (B).

8) Fry scare line (Fig. 102)

The fry scare line, locally called "suram-baw" consists of one scoop net and a long scare line carrying streamers of coconut leaves. The scare line is 30 to 50 m long and is operated by two fishermen. This is used in shallow waters, along the shore and over sand bars. In fact, this device is more effective for

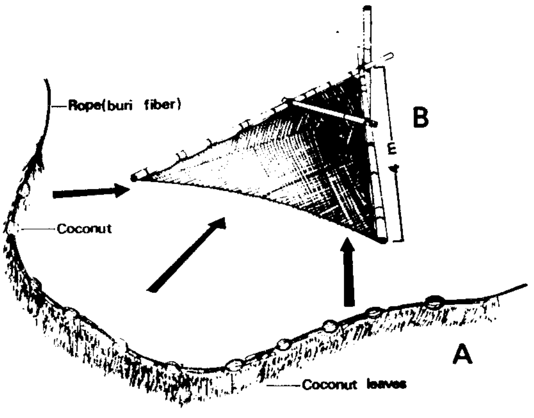


Fig. 102. Fry scare line (A) and scoop net (B).

catching bangos fry than sugpo because it sweeps only near the surface layer of the water down to about 20 cm deep.

9) Fry scoop net (Fig. 103)

The scoop net, varies from place to place, and is used to collect fry hiding or clinging to mangrove roots, water grass or other objects in brakishwater areas.

Discussion

Among nine kinds of gear, fry lures and fry scare lines exploit the tendency of sugpo fry to cling to solid objects. The same is true of the scoop net which captures the clinging fry. The use of the fry filter net, the Capiz patterned filter net, the triangular net, and fry bulldozer is also based on the migrating behavior of the sugpo fry to shore waters and penetrating brackish-waters such as mangrove areas with an incoming tide. Some of them are also used for collecting bangos fry.

During the present survey, it was observed that the fry collectors after selecting sugpo fry discarded onto the dry sand the remaining planktonic organisms which contained plenty of potentially useful prawn fry as well as fry of finfish and crabs.

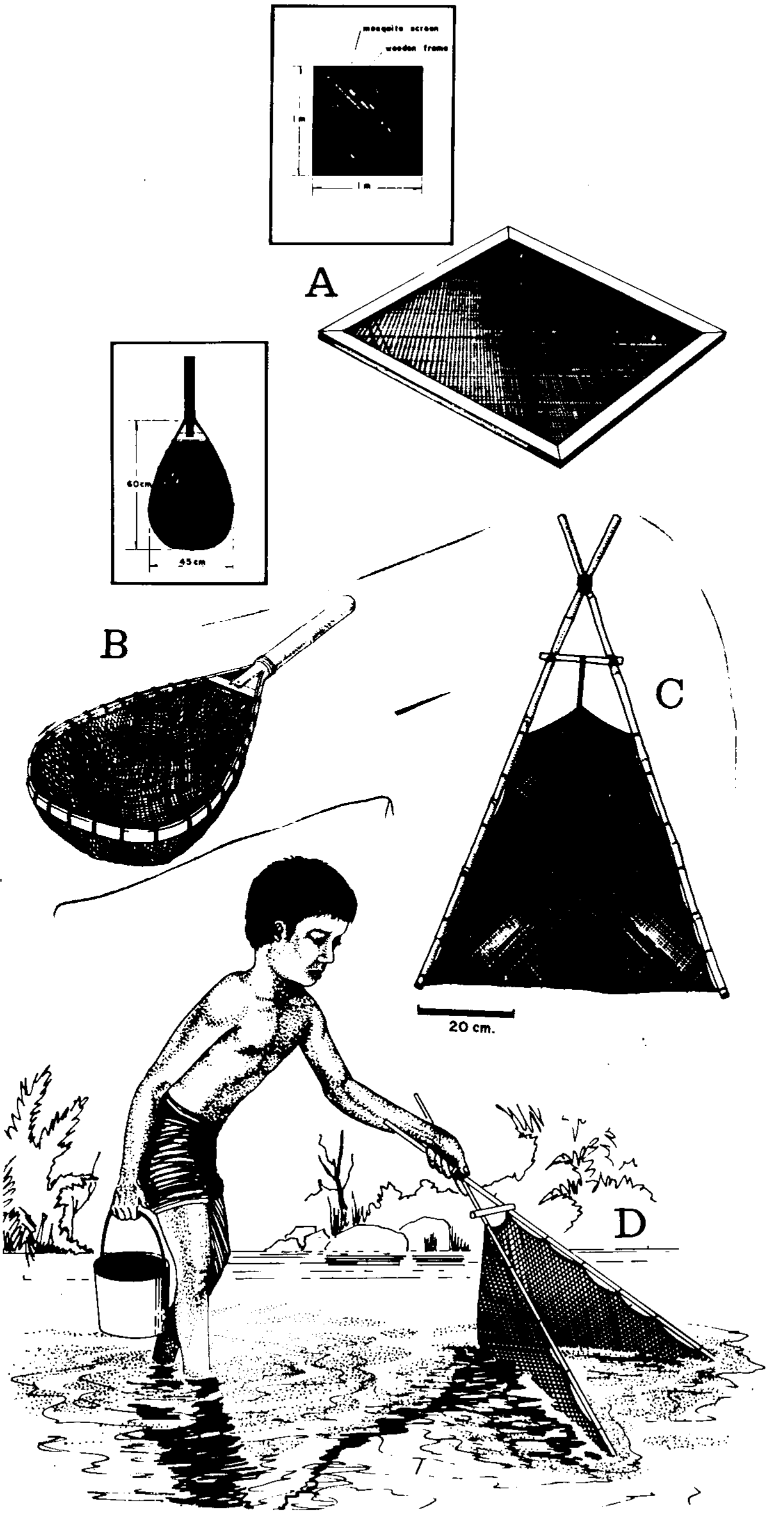


Fig. 103. Fry scoop nets (A,B,C) and operational view (D).

The present author, therefore, strongly recommends the following: 1) Sugpo fry are generally few in number, while other cultivable fry such as *P. indicus* and *P. merguiensis* are almost always predominant in shore waters. The collection of these more abundant fry is highly recommended for shrimp cultivation in brackishwater pond, which will result in more income for rural people. 2) After sorting out the prawn fry, the remaining organisms such as finfishes and crabs, should be returned to the sea which is only one meter or two away from the sorting place, to conserve natural resources.

X-2 Offshore migration

A. Migration of adult

i) Tagging and releasing experiment (Fig. 104)

One of the methods used to elucidate the migration route is the release and recapture of tagged prawns. It is envisaged that the age and growth data obtained would be of value, particularly to prospective prawn culturists.

Serially numbered yellow, red or green Dymo tapes with size 9 x 18 x 0.2 (thickness) mm were attached to the postero-dorsal margin of the 6th abdominal segment of prawn by means of a short length of thin flexible nylon line. Both ends of the nylon line were softened using heat from smoking mosquito coil after piercing through a hole in the margin of prawn by means of a small needle.

Two hours after tagging, they were manually and carefully released one by one at shallow area (less than 1.5 m deep). Posters outlining the objectives of experiments and featuring an illustration of a tagged prawn with explanation not only in English but also in local dialect (Ilongo) were given to the Barangay Captain (village chief) or distributed to fishermen. Fishermen were requested to return the tag, as well as prawn if possible, with necessary information: date, locality and fishing gear. A reward amounting to ₱10 (about 1.3 US dollars) was paid for the return of each tag with or without prawn.

The field experiment was carried out twice, on September 12-14, and on October 12-13, 1977. Experimental animals were obtained either from fish corrals or prawn ponds at Batan Bay and its vicinity. The tagged prawns consisted of 168 (47 males and 121 females) on September and 177 (66 males and 111 females) on October. The carapace length varied between 32.8 and 60.1 mm with an average of 47.5 mm in male and 35.2 and 71.6 mm with an average of 58. 2 mm in female.

Results of recapture are shown in Fig. 104. Most of animals were recaptured in fish corrals and were returned within one week of release. The movement of recaptured prawns in this study suggests that adult *P. monodon* released inside the bay have a tendency to move towards the outer (deeper) portion of the bay (September experiment).

On the other hand, when they were released near the mouth of the bay, some of them moved into the interior (shallow) portion while the others moved to the deeper water (October experiments). These results suggest that some adults migrate into the bay from deeper portion, possibly accompanying the incoming tidal current, although the majority moves towards the deeper portion.

The recovery rate was 7.1 % in the September experiment, and 13.6 % in October. The latter resulted in better recapture than the former, owing to many captures (15 individuals) by fish corrals near the releasing point.

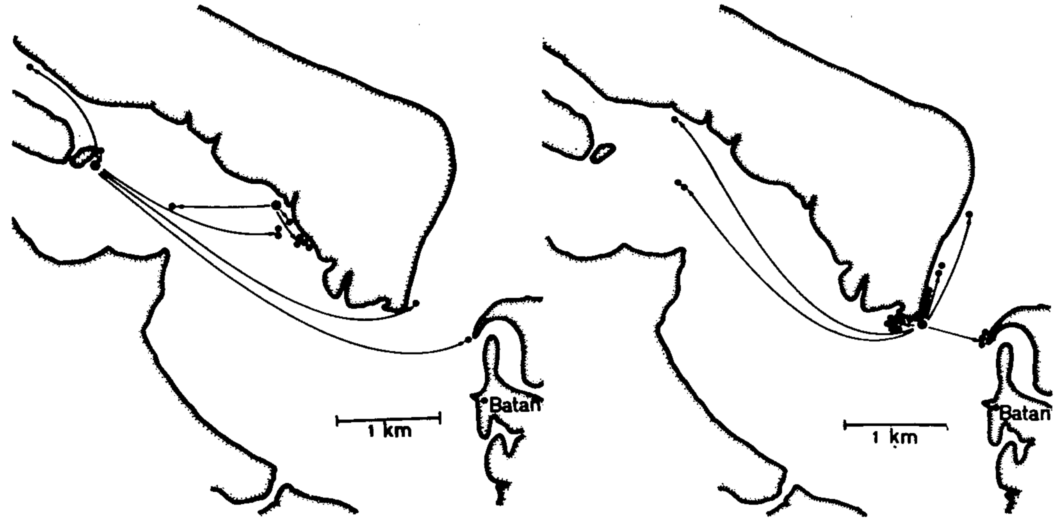


Fig. 104. Migration path of tagged *P. monodon* in Batan Bay. One small solid circle represents one captured animal. Left, experiment on September 12-14, 1977; right, October 12-13, 1977.

ii) Size distribution by habitat

In general, the carapace length of *P. monodon,* is larger in specimen from outer littoral area (Fig. 107) than those from inner littoral area (Fig. 106), while those from estuary are smallest (Fig. 105).

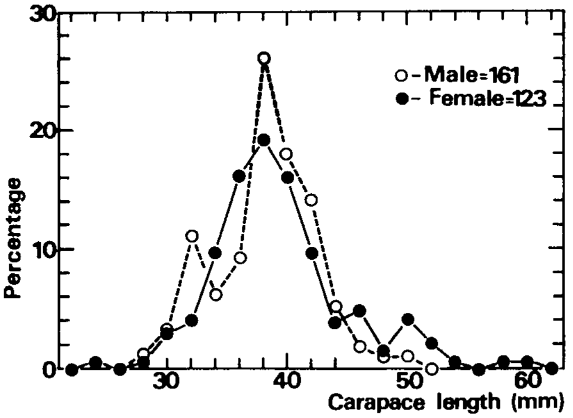


Fig. 105. Size distribution of male (open circle) and female (solid circle) *P. monodon* from brackishwaters.

It is interesting to note that there is no size difference between the sexes in specimens from estuaries, showing modal carapace length 38 mm (Fig. 105), while in inner littoral areas such a difference exists with modal carapace length of 48 mm in males and 56 mm in females (Fig. 106). The difference is greater in the outer littoral area with carapace length of 50 mm in male and 62 mm in female (Fig. 107). These phenomena may suggest the migration toward the littoral area from the estuary while growth continuous particularly in females.

B. Seasonal abundance

i) *P. monodon*

Fig. 108 shows the seasonal abundance of *P. monodon* caught in a fish corral at the mouth of Batan Bay and trawled by R/V SEAFDEC I and SEAFDEC II off Tigbauan. In terms of the number of individuals, there seems to be two peak occurrences in a year, viz. March, and September (off Tigbauan) or March and

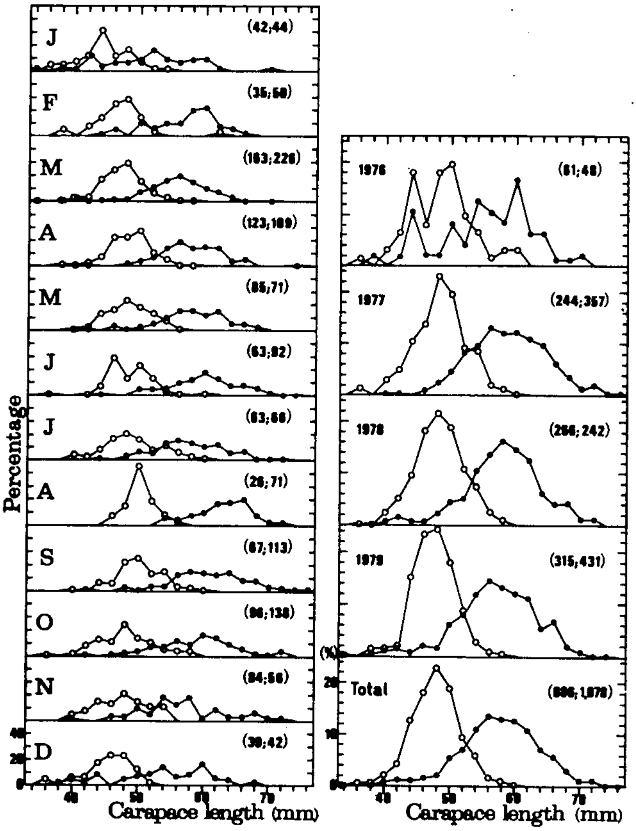


Fig. 106. Carapace length distribution of *Penaeus monodon* caught with fish corrals at the mouth of Batan Bay, Philippines, from 1976 to 1979. Open circles represent males and solid circles females. The first number in parentheses at each month or year indicates the size of samples males, and second females. The variation of sample is due to the different number of fish corrals visited during a month or year.

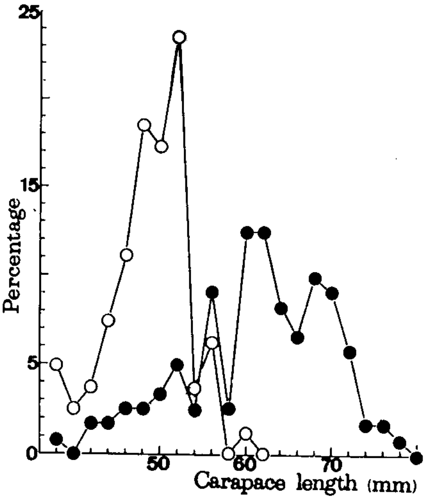


Fig. 107. Size distribution of male (open circle) and female (solid circle) *P. monodon* from off Tigbauan by means of otter trawler and gill nets, 1976-1978.

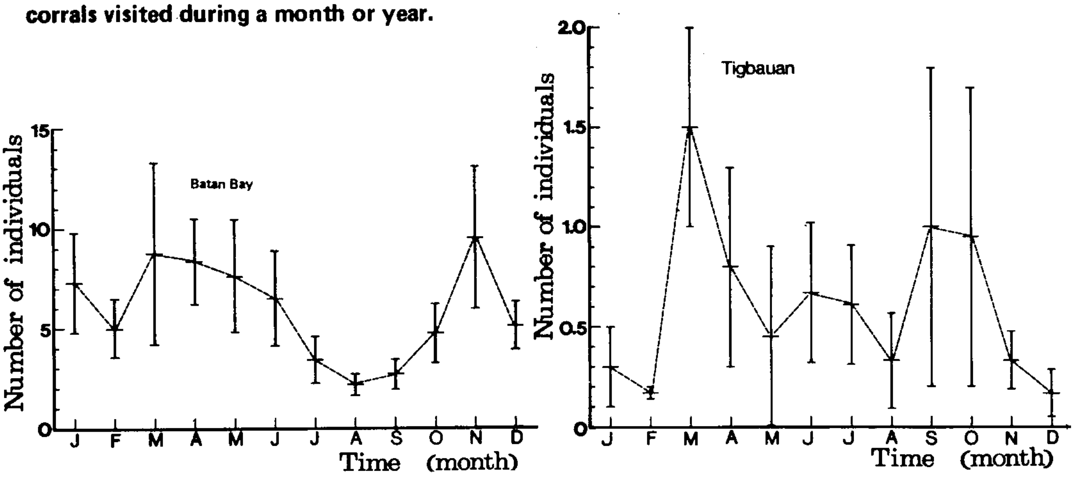


Fig. 108. Monthly occurrence of *P. monodon* caught with a fish corral (Batan Bay), 1976-1978 and with a one-hour experimental trawling (Tigbauan) 1976-1978. Horizontal bars represent mean, vertical bars standard deviation of mean.

November (Batan Bay), although considerable fluctuation occurred from year to year.

ii) Other Penaeid prawns

Based on the data gathered in Batan Bay from June 1976 to December 1978, there appears to be two peak occurrences of penaeid prawns consisting of 10 species including *P. monodon* viz. May and September as shown in Table 13.

Table 13. Mean monthly catch of penaeids per fish corral at the mouth of Batan Bay from 1976 to 1978. For each species number of individuals are shown on the top line and body weight (g), on the bottom line.

Month Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
P. monodon	2.70 164.95	2.75 251.60	3.90 338.65	6.15 512.10	2.35 182.70	6.93 607.20	3.93 321.43	1.77 197.03	3.90 447.23	7.10 674.47	10.50 883.17	5.23 379.30	4.77 413.32
P. semisulcatus	0.05 2.00	0.50 14.85	2.10 69.70	1.65 47.85	1.65 19.40	12.00 198.40	8.37 158.90	8.47 197.80	6.26 132.60	15.40 379.73	3.86 93.83	0.93 23.27	5.10 111.53
P. merquiensis	1.35 16.55	5.30 65.95	1.10 23.00	8.40 131.95	49.35 841.10	3.40 44.90	16.40 233.75	5.55 77.60	23.65 387.30	32.20 529.15	35.90 581.25	2.60 43.50	15.43 248.00
P. indicus	1.10 17.30	2.60 25.75	0.20 2.10	1.50 20.15	5.65 71.15	0.95 9.45	1.90 23.85	0	0.60 8.25	1.40 20.10	7.10 93.45	8.25 87.30	2.61 31.57
P. latisulcatus	0	0.40 7.30	0.50 9.55	0.90 13.60	6.05 108.30	10.47 147.13	2.57 39.63	0.23 6.30	5.53 129.10	2.27 60.20	0.53 14.27	1.07 18.03	2.54 46.12
P. japonicus	0.05 1.60	0.10 1.40	0.75 10.35	0.50 5.30	0.65 11.20	1.13 17.20	0.03 0.40	0.33 8.30	0	0.07 0.77	0.33 4.43	0.23 2.70	0.35 5.30
M. ensis	0.20 1.55	7.15 45.15	4.10 39.85	11.25 106.10	40.70 233.05	11.57 83.87	12.83 108.47	7.20 50.97	64.67 464.50	47.33 341.57	22.23 180.07	0.93 7.30	19.18 138.54
M. endeavouri	0	0.50 9.40	1.00 14.25	1.15 17.75	3.35 40.40	8.77 101.57	1.97 23.87	3.87 43.60	15.43 219.97	5.27 56.03	1.37 17.67	0.43 4.83	3.59 45.78
M. dalli	0	0	0.10 1.05	0 —	2.10 6.15	0.07 0.33	0.10 0.23	0	0	0	0.17 0.50	0	0.21 0.69
T. fulvus	0	0	0.05 0.20	0	0.95 4.60	0.07 0.20	0.13 0.37	0.33 1.33	4.00 15.17	0	0	0	0.46 1.82
TOTAL	5.45 203.95	19.30 421.40	13.80 508.70	31.50 854.80	112.80 1518.05	55.36 1210.25	48.23 910.90	27.75 582.93	124.04 1804.12	111.04 2062.02	81.99 1868.64	19.67 566.23	54.24 1042.67

Dominant species was *Metapenaeus ensis* followed by *P. merguiensis*. Among all species, *P. monodon* has the highest commercial value owing to its larger size, although the number caught is not abundant. On the other hand, *M. dalli* and *Trachypenaeus fulvus* have poor commercial value owing to their smaller sizes and few numbers caught.

C. Local occurrence of *P. monodon*

The well-developed fishing areas for *P. monodon* as well as other penaeids are shown in Table 14 and Fig. 109, based mainly on the results of experimental

Table 14. Fishing grounds of *P. monodon* and other penaeids surveyed in the Philippines.

No.*		No.*		No.*	
	LUZON		VISAYAS		MINDANAO
1.	Lingayen Gulf	4.	Batan Bay	8.	Dapitan Bay
2.	Ragay Gulf	5.	Visayan Sea	9.	Panguil Bay
3.	San Miguel Bay	6.	Panay Gulf	10.	Illana Bay
		7.	Cogtong Bay	11.	Bislig Bay

* Corresponds in Fig. 109.

trawlings and commercial prawn landings and partly on hearsay from fishermen.

D. Diel occurrence of *P. monodon*

According to results of experimental catch from fish corrals at the Batan Bay, a total of 36 individuals were caught at night, while only five at daytime out of nine experimental hauls each. Thus, it can be said that *P. monodon* move mostly at night and seldom do so during daytime. From this evidence, it can be said that the giant tiger prawn is nocturnal. This behavior was also proven by laboratory experiments. During daytime, *P. monodon* burrows partially in the mud (Fig. 111) while it is active at night. Aside from the above observations, it is generally admitted by the fishermen of commercial trawlers that the catch of *P. monodon* as well as that of other penaeids are more abundant at night.

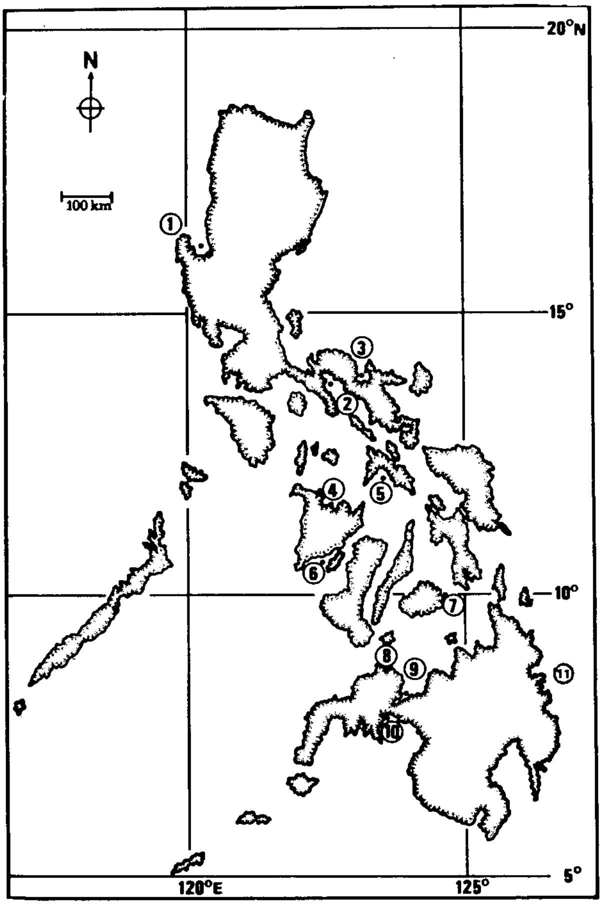


Fig. 109. Map showing the fishing grounds of *P. monodon* and other penaeids surveyed in the Philippines (see Table 14 for detailed explanation).

E. Relation to moon phase

Based on the data covering 125 days, from March 31 to May 24, and from June 19 to August 27, 1979, *P. monodon* were mainly abundant during the new moon phase followed by the first or last quarter (Fig. 110). On the other hand, during the full moon period, *P. monodon* poorly appeared in spite of the big water movement. This phenomenon strengthens the observation that the giant tiger prawn prefers dark conditions to bright ones, probably avoiding their predators such as finfishes.

F. Prawning gear and the methods

The present section deals with the description of gear which have been traditionally used in the Philippines. This study will lay a ground work on prawn fisheries for private sectors who are interested in prawn culture.

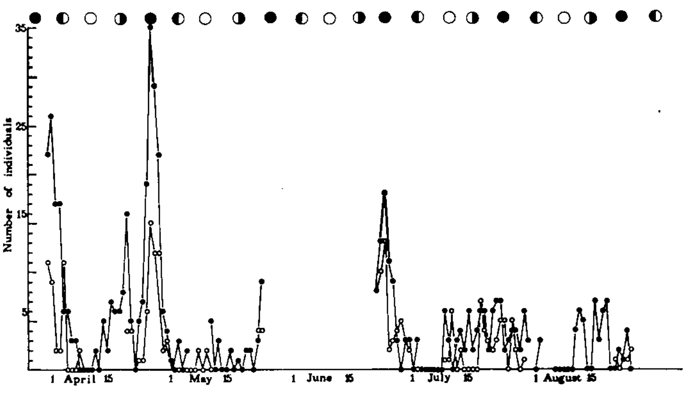


Fig. 110. Occurrence of *P. monodon* caught with each fish corral related with moon phases, at the mouth of Batan Bay. Solid circles denote catch from one fish corral (C-35) and open circles from another (C-36).

Fig. 111. Adult *P. monodon* burrowing partially in the mud.

Illustrations were based mainly on actual observations and partly on color photographs. The gear consisted of eight kinds and could be classified into two groups: set impounding net and mobile impounding net (Table 15).

Table 15. Traditional prawning gear used in the Philippines today (local names are enclosed in parentheses).

Prawning gear	Area operated
A. Set impounding net	
1. Fish corral (baklad, bungsod, tower)	Mouth of brackishwater river, bay
2. Prawn trap (bakikong, paabang, aguila)	Fishpond, fishpond canal
3. Filter net (saluran, sangab, taan)	Mangrove area, fishpond
4. Lift net (bintahan, sumbadahan)	Brackishwater river, bay
5. Lever net (salambaw)	Mouth of brackishwater river, bay
6. Cover net (pingpong)	Mangrove area, brackishwater river
B. Mobile impounding net	
7. Triangular net (hudhud, sagap, sayud-sud, sudsud)	Mangrove canal, brackishwater river
8. Skimming net	Bay, mangrove area

1) Fish corral (Fig. 112)

The fish corral locally known as "baklad", "bungsod", or "tower" consists of guide lines and a codend. The guide lines are made of bamboo poles, wooden poles or split coconut trunks while the codend is made of split bamboo known as "banata" or synthetic nets. Harvesting is done during low tide, usually in the early morning. At present there are three kinds of fish corrals in use. One is for gathering the fish and prawns to a permanent terminal compartment or codend which is immovable or undetachable. To catch the shrimp, one of the fishermen goes inside the codend through a narrow channel leading to a guiding wall, and dives under the water with a spear or a scoop net.

The second type is equipped with a detachable circular codend which is lifted elevator like by four ropes with the aid of pulleys. After harvesting it is lowered into the water and one fisherman unties the entrance of the codend. A terminal compartment made of a square or a rectangular cage approximately 1.5 m tall is lifted to the surface by four ropes attaching to its corners and wound around a perpendicular piece of bamboo that is rotated along a pair of parallel bamboo bars like a winch. A man gets inside the cage through a hatch to collect the fish. After harvest, the cage is lowered and reattached to the fish corral.

The last type is located in shallower areas. The cage is merely detached and carried to the shore by two to four men and then replaced after harvest. Fish corrals located inside the bay, river mouth and mangrove area are smaller, while those facing the open sea are larger in construction.

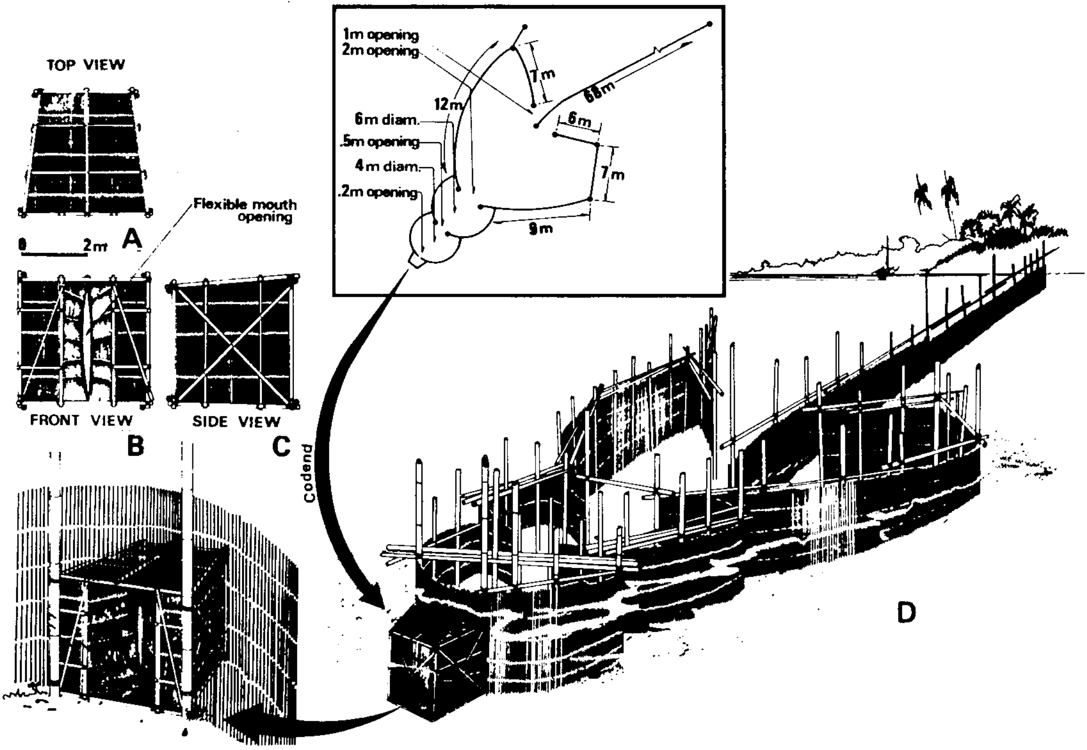


Fig. 112. Fish corral (A, B, C) and operational view (D).

The prawn and shrimp migrate from shallow nursery area to open sea for mating, spawning, when almost adults. During the time they are mostly trapped by the fish corrals particularly during night time as they are nocturnal.

2) Prawn trap (Fig. 113)

The prawn trap consists of bamboo or split coconut trunk as a supporter, bamboo matting "banata" as a guide screen or leader, and one codend as a catching chamber.

The bamboo screen leads prawn to a codend, located diagonally from the fishpond dike. The construction is basically the same as the fish corral, however, the trap's bamboo screen is generally not so long, usually less than 10 m, and is situated in narrow mangrove channel, creek and inside or outside fishponds. It has no detachable codend for harvest, thus harvest is usually done with a scoop net.

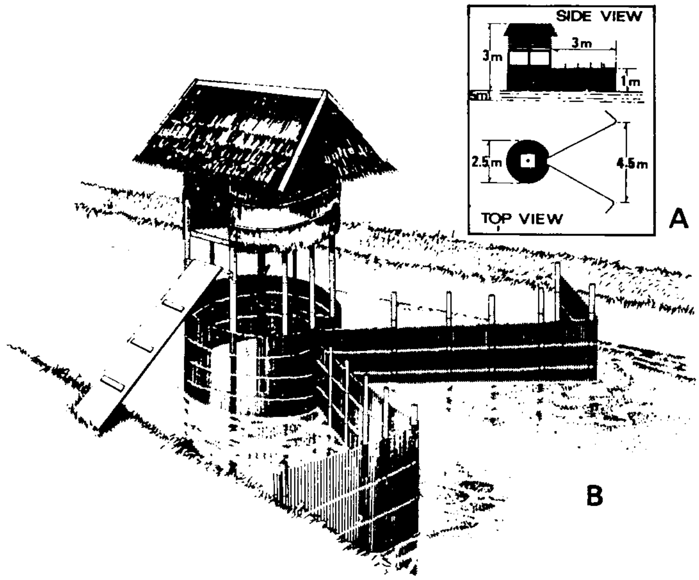
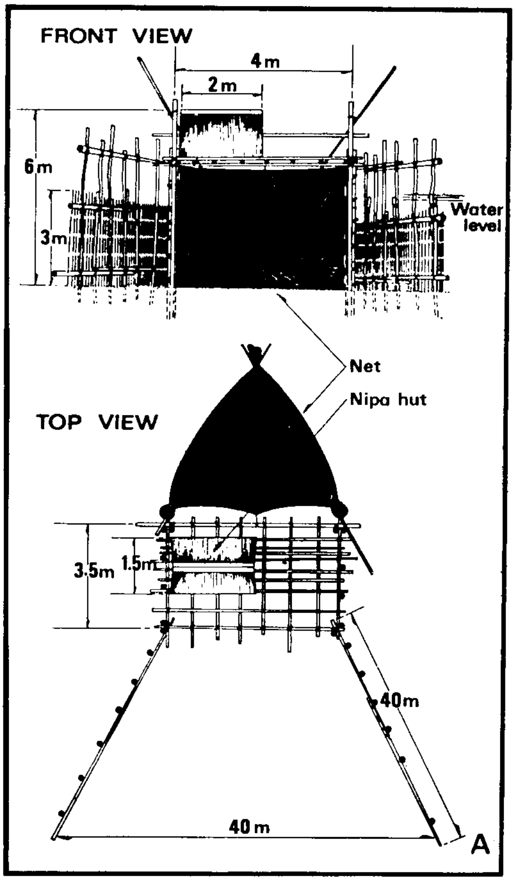


Fig. 113. Prawn trap (A) and operational view (B).

According to Delmendo and Rabanal (1973), prawn traps are locally called "bakikong", "paabang", and "aguila" based on their construction and location. Basically the construction as well as operation is similar to fish corrals. According to the caretaker of a prawn pond, the harvest is made at night during flood tide, as the prawns move towards the trap, due probably to their search for fresh seawater.

3) Filter net (Fig. 114)

The filter net is locally called "saluran", "sangab" or "taan". Construction materials for the filter net are coconut trunks for the posts, bamboo matting for the guide lines and synthetic nets for the codend. The filter nets are seldom constructed singly and are usually joined in series across a river mouth or shallow channel. A V-shaped leader is used to guide the fishes into a conical net bag which is set when the water is receding and usually faces upriver. A few filter nets "saluran" are constructed with opposing V-shaped leader and can be operated during ebb and flood tides.



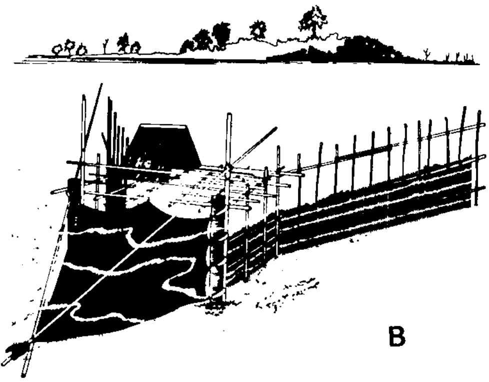


Fig. 114. Filter net (A) and operational view (B).

The net is supported with rattan loops which slide down a pair of perpendicular bamboo poles positioned at the inner end of the leaders, thus the net can be raised or lowered down. The length of the net is usually 15 to 20 m but varies according to location.

Harvest is done once or twice during a particular tide by reversing the setting operation. The gear is normally operated at night but may be operated during the day when the water is turbid, especially on continuous rainy days. This gear operates on the principle of filtering fishes and shrimps when they are partially disoriented by the water current and when they are migrating towards open sea.

The "bukatot", "diakos" and "saplad" (Domantay, 1973) are modified filter nets set against the current inside tidal creeks, river mouth, or mangrove swamp.

4) Lift net (Fig. 115)

A square platform raised about 0.5 m above the highest tide and supported by bamboo stakes in the framework is normally required. Operation is done by lowering a weighted square mouthed net, almost as wide as the platform above, to the bottom by an improvised wooden winch. Pulleys are provided at each corner of the platform where a lifting rope is passed through, to the corners of the net. While the net is at the bottom, the fisherman lights a kerosene lamp to attract fishes and shrimps and also to aid his sight. The fish and shrimp are further concentrated below the middle of the platform center by gradually dimming the light. Hauling is done manually by slowly rotating the winch until the edge of the net is above water surface. The catch is concentrated in the center and scooped by a long handled scoop net operated from the platform. Several hauls could be made

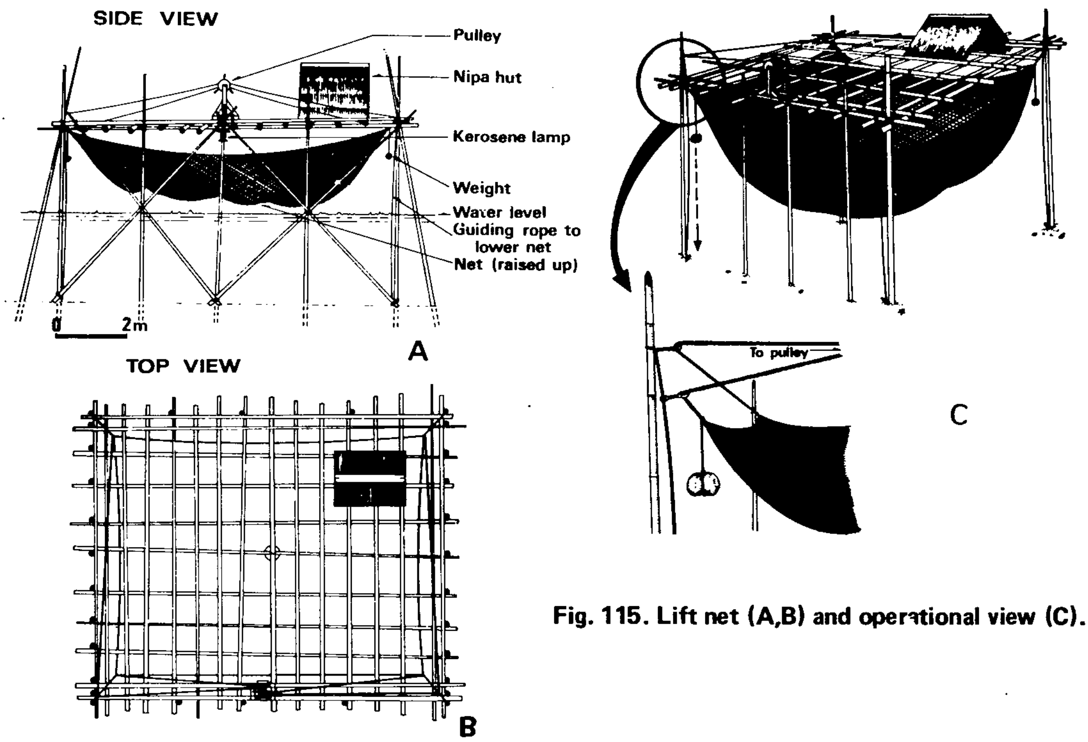


Fig. 115. Lift net (A,B) and operational view (C).

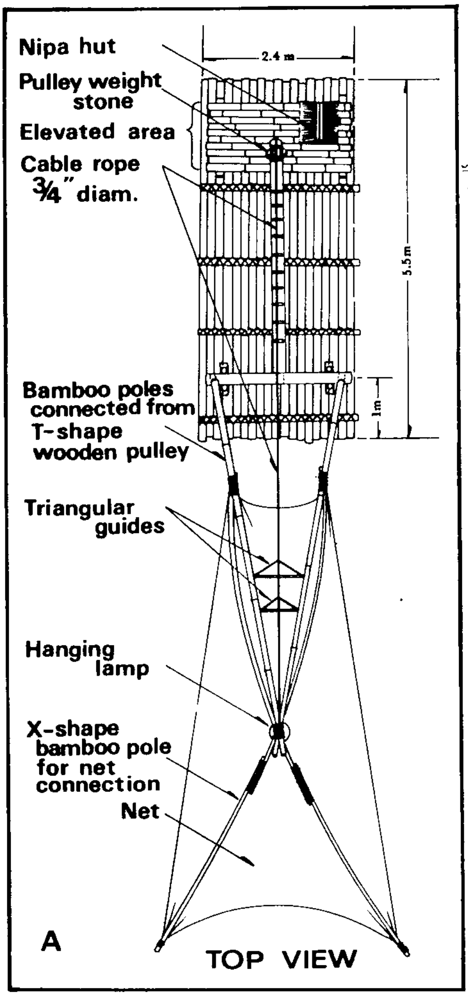
per night depending on the abundance of the catch. This gear locally called "bintahan" or "sumbadahan" does not depend on the tidal current and in fact should not be located where there are strong currents. To counteract the net overturning due to currents, stones are attached to the corners of the net to keep it in shape. The sag at the center of the net should not be less than 1.5 m for more effective catching. Sometimes the fishermen spread baits, viz. trash raw, salted and sun dried fish inside the net. At night prawns seek for food and are attracted by the light, thus the lift net is effective for their capture.

5) Lever net (Fig. 116)

Locally known as "salambaw" its operation is similar to a lift net but the gear is mobile since it is operated from a bamboo raft. The net framing is made of the strongly curved bamboo poles forming half or quarter circles, tied centrally across each other from whose tips the four corners of a concave net are tied. The frame and net are hung from the terminal of a bipod boom extending from one end of the raft, providing ample space for the frame and net to be submerged. In operation, the raft is anchored, then the boom is lowered from an angle of about 70 degrees to a lesser angle by reducing the counter weight of stones or rocks on a plank lever made of bamboo or wood tied to the raft, until the net is finally submerged. While lowering the boom, the control rope is carefully released while the weights are removed. There must be enough stones to raise the boom back. To haul, the procedure is reversed. The catch is scooped by a long handled scoop net. Like other night operated gear, light is used to attract fishes. To transfer from one fishing area to another it is moved by poling and at times it may also be pulled by a motorized boat.

6) Cover net (Fig. 117)

This is a circular-type cover net with a long bamboo handle, locally called "pingpong". At night, usually during low tide, a fisherman walks along the



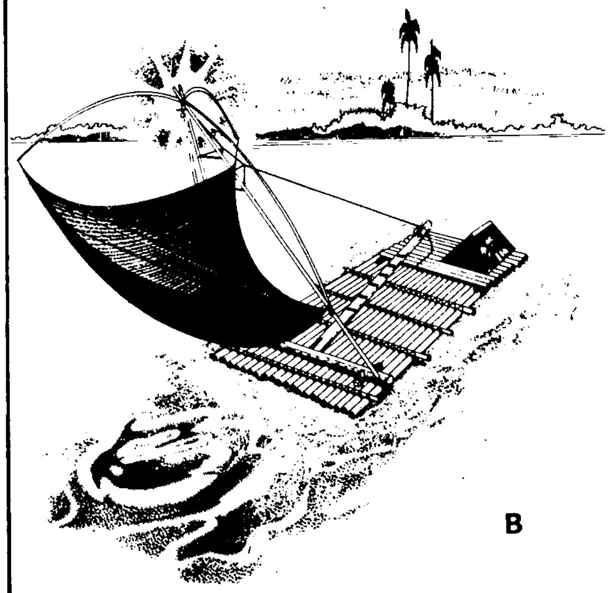
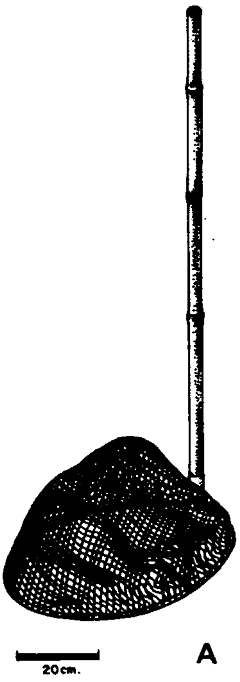


Fig. 116. Lever net (A) and operational view (B).



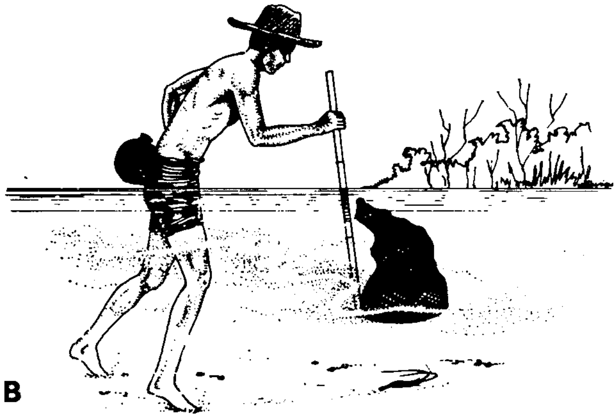


Fig. 117. Cover Net (A) and operational view (B).

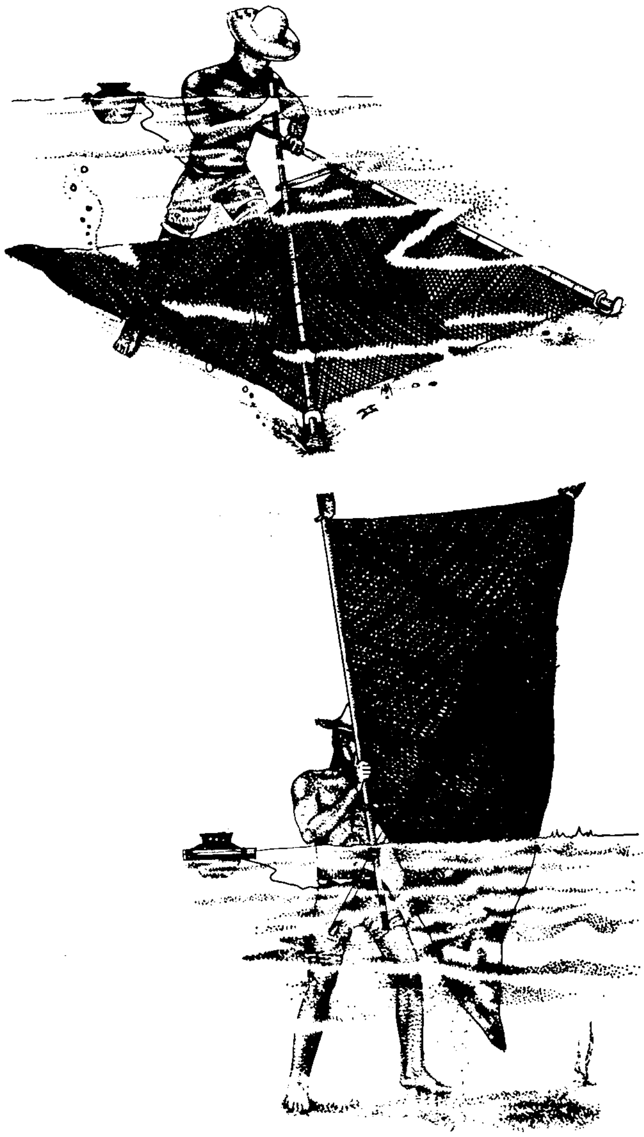


Fig. 118. Operational views of triangular net (slightly modified from Umali, 1959).

shoreline or mangrove creek with a kerosene lamp and when he finds a prawn, suddenly covers it with this net and then grasps it with his other hand. If he uses a banca, he can catch prawns in deeper waters. The kerosene light not only guides the fisherman, but also attracts the prawns. When attracted by light, the prawns move slowly and are easily captured even by hand.

B. Mobile impounding net

7) Triangular net (Fig. 118)

The triangular net, locally called "hudhud", is also called push net or scissors net because of the method of operation and shape.

It is operated by one man wading chest deep in mangrove creeks, brackishwater rivers, and sometimes in shore waters where a great number of *Acetes* sp. (small primitive shrimp, locally called "hipon" or "alamang") can be caught.

8) Skimming net (Fig. 119)

The area available for the operation of skimming net is covered by municipal ordinance and is limited to the shallow interior portion of bays.

The apparatus consists of a motorized boat, usually operated by two men with a single piston engine of up to 10 horsepowers, a triangular net, a V-shaped bipod frame and a kerosene lamp. The frame is made of a pair of eight bamboo poles bolted on one end, with both the free ends provided with wooden flat shoes so they can glide over the mud bottom, when set on a slightly inclined position. The net is

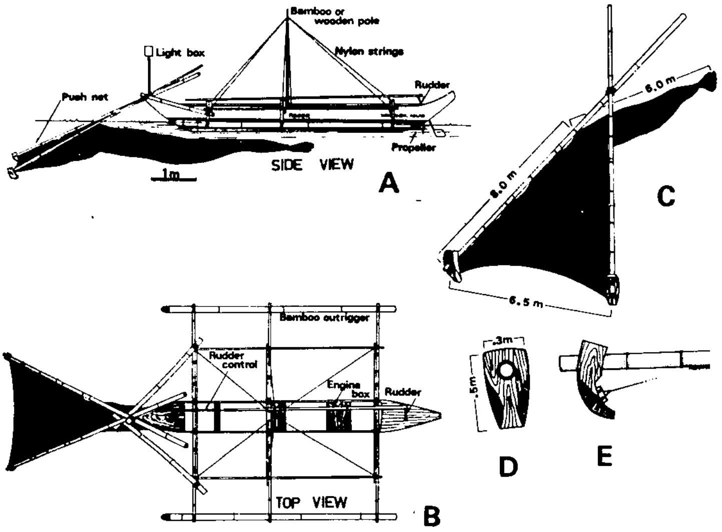


Fig. 119. Motorized boat used for skimming net (A, B), skimming net (C) and wooden flat shoe (D,E).

tied to a frame that is attached to the bow of the boat. As the boat moves forward, the net is set in place almost directly under the boat with the codend just a meter or more ahead of the screw. The whole width of the frame spread in front of the net opening is provided with a scare lead line. To haul, the boat is stopped, the codend is lifted and its contents are emptied into a sorting box. A kerosene lamp is normally tied to the boat front to attract fishes and shrimps and also as a navigational aid. Operation is further enhanced when the water is turbid. The skimming net is advantageous as the net is located infront of the boat, minimizing the disturbance to the prawn generated by the engine and screw, compared with a baby trawler.

Discussion

According to fishermen, prawns are mainly nocturnal, thus the fishing gear such as skimming nets and trawlers are operated at night particularly during the new moon phase. Fish corrals are operated day and night and the harvest is made in the early morning. Furthermore, many existing lift nets and lever nets use kerosene torch lights at night. On the other hand, filter nets and fish corrals are adapted to the migratory behavior of prawns which tend to move towards the open sea with the outgoing tidal current particularly at night or after a heavy rain. For these reasons almost all types of gear are located in places where there are strong currents and face inshore or upstream to enable the capture of prawns migrating to the open sea. During the present survey, it was oftentimes observed that several types of gear such as skimming nets and baby trawlers were operated in mangrove areas, the interior portion of a bay and big rivers which are important nursery grounds of prawns, shrimps and other useful marine species. The catch consist mainly of juveniles and/or adolescents which command low market price due to their smaller sizes. Capture of these small shrimps should be banned to conserve aquatic resources.

As a general observation, it is very interesting to note that the types of gear mentioned above are well adapted to the behavioral patterns of shrimps and prawns and were developed and modified by rural fishermen through their experience. The gear sometimes give scientists who are engaged in prawn ecology and biology valuable information in prawn behavior.

Needless to say, most of the gear described here are also used for catching other commercially important animals such as crabs and finfishes.

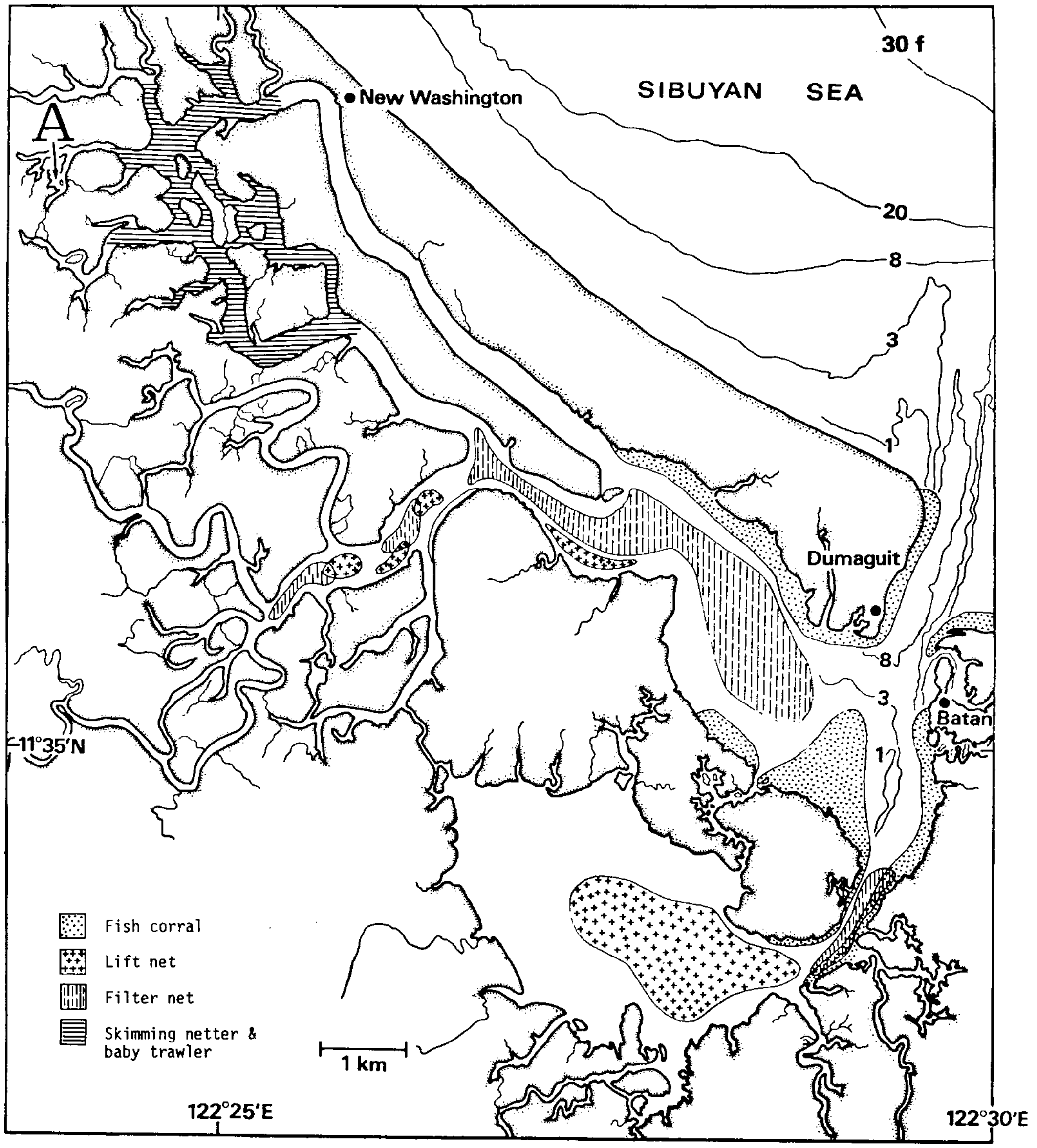


Fig. 120. Map showing distributions of four types of prawning gear in Batan Bay.

X-3. Habitat

The habitats of *P. monodon* as larvae, juveniles, adolescents, subadults and adults are roughly divided, as in other parts of the world (Burkenroad, 1934; Racek, 1959) and based on the data found during the present study, into three environments as follows:

A) Estuarine area – This area comprises the upper tidal parts of rivers down to the mouth, interior and middle portions of bays, and mangrove swamps. These waters vary from almost fresh through slightly brackish to seawater, and changing salinity and temperature due to the influence of seasonal river flood and tidal fluctuations are exhibited. Bottoms are mainly muddy with rich detritus and are dark brown in color. Water depth ranges from 0 to 7 m.

B) Inner littoral area – This area covers river mouths, or outer parts of bays up to two km offshore where coastal water predominates. The water is generally saline with a slight variation due to tidal action. The bottom consists of mud or sandy mud, brown or grey in color. The depth ranges from 7 to 20 m.

C) Outer littoral area – This area has water of full salinity and extends from two km to the edge of the continental shelf. The water temperature and salinity are stable but exhibit a slight seasonal fluctuation. The bottom consists of mud and is grey in color with depths ranging from 20 to 70 m, the deepest at which *P. monodon* has ever been caught in the Philippines.

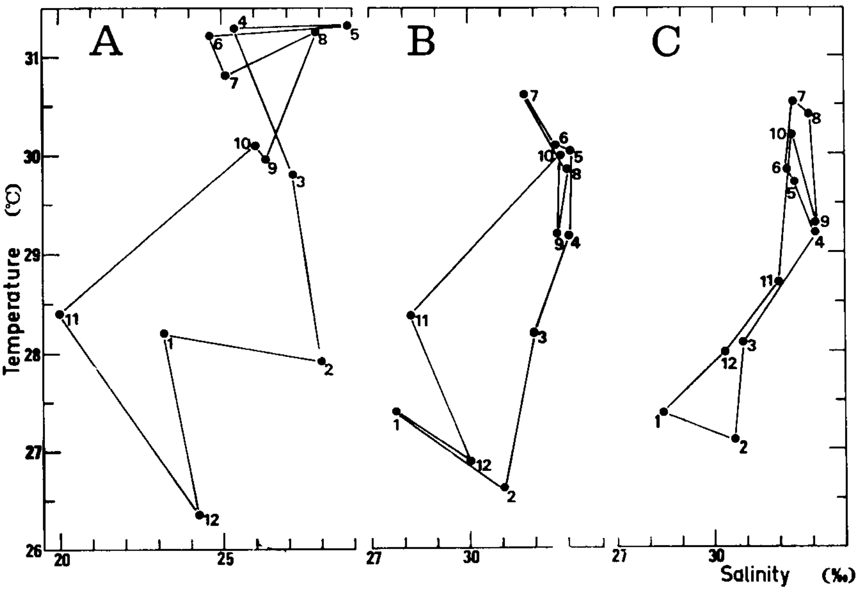


Fig. 121. Mean monthly water temperature and salinity at Batan Bay and its vicinity. A. estuarine; B. inner littoral area; C. outer littoral area.

Mean monthly water temperature and salinity are shown by habitat in Fig. 121.

Discussion and conclusion

As mentioned earlier, eggs of *P. monodon* sink slowly in still seawater to the bottom and hatch 12 hours after spawning. The newly hatched nauplii exhibit strong positive phototaxis, and probably undergo diurnally vertical migration in the plankton. In addition they are subject to movement by current. The protozoeal stages probably behave in a similar manner to the nauplius, although they have more recognizable swimming activity than the nauplii.

Once metamorphosed into the mysis stage, they have considerable swimming ability accomplished with the exopods of the maxillipeds and pereiopods (Motoh, 1979), and start to seek lower salinity water leading to the nursery ground. In fact, mysis larvae seem to prefer lower salinity to normal seawater and show a higher survival in lower salinity water under laboratory conditions as shown in table 3 of Mochizuki (1979). Some precocious myses were found at the mouth of the Batan Bay migrating to the nursery ground.

After metamorphosing into megalopa or postmysis, they actively seek tidal currents and migrate towards the shore presumably utilizing these tidal currents to penetrate into brackishwaters where their nursery ground exists.

King (1971) found a positive correlation between wind direction and number of postlarval brown shrimp caught on the flood tide in a Texas tidal inlet. His results indicate that more postlarvae were captured when the wind direction was offshore. Findings in the present study at various localities are in agreement with King's as shown in Table 11 and Fig. 85. According to fry collectors, more fry are available when the shore water is a little bit rough due to offshore winds and when the water is slightly turbid, thus the postlarvae are generally abundant during northeast and southwest monsoons.

The schematic explanation of the migration of postlarval *P. monodon* may be explained, although some of the description are still hypothetical or cited from work on other postlarval *Penaeus* (Hughes, 1969; Barber and Lee, 1975).

From the mysis stage the larvae can detect a gradient of salinity. Mostly during late megalopa stage (early postlarvae), they migrate to shore waters as follows:

(1) The fry, particularly after metamorphosing into the late megalopa, migrate toward shore waters on tidal currents.
(2) Once they penetrate into the inshore waters, they sink to the muddy bottom.
(3) Between flood tides, they stay on the mud bottom and exposed in relatively lower salinity water from river discharge.
(4) When water temperature is relatively low and is accompanied by higher salinity water on the flood tide, they become active and penetrate upstream in brackishwater river or to the interior portion of the bay. They may eventually reach up to waters with salinity of 4 $^{o}/oo$.

The juveniles penetrate into shallow water area of low salinity and encounter fewer predators and more food (Gunter, 1961; Odum and Heald, 1972). Physiologically, penaeid juveniles have great tolerance not only to salinity but also to temperature fluctuations.

Some areas are often exposed to the air during the lowest tide and salinity as well as temperature fluctuate greatly.

The fry protect themselves from numerous predators by clinging to various objects, e.g. mangrove roots, leaves of water plants, twigs as evidenced by the grass lures for fry collection. The habitats of juveniles might be highest topographically among the habitats in the life span from the topographic point of view.

In general, juveniles are found in great numbers in shallow inshore waters such as mangrove creeks and the upper portion of brackishwater rivers.

At the end of the juvenile stage when about 15 mm CL, the prawns migrate back downstream. After molting into adolescents, they move downstream into deeper waters and show remarkable growth during the period. Their habitat becomes relatively extensive. In addition, they are now large enough to be commercial size and subsequently they are exposed to capture by skimming netters or baby trawlers in the interior portion of the bay or by lift nets and lever nets in the lower portion of brackishwater river. The diagram of the life history of *P. monodon* is shown in Fig. 122.

XI. GENERAL DISCUSSION

During the present study, the reproductive systems of the giant tiger prawn were examined. However, the mechanism of copulation with regard to the function of the petasma as well as the appendix masculina and the relationship between the size of a spawner and number of ovarian eggs were not well documented due to the difficulty of the observation and lack of specimens involved. More work on this matter should be carried out.

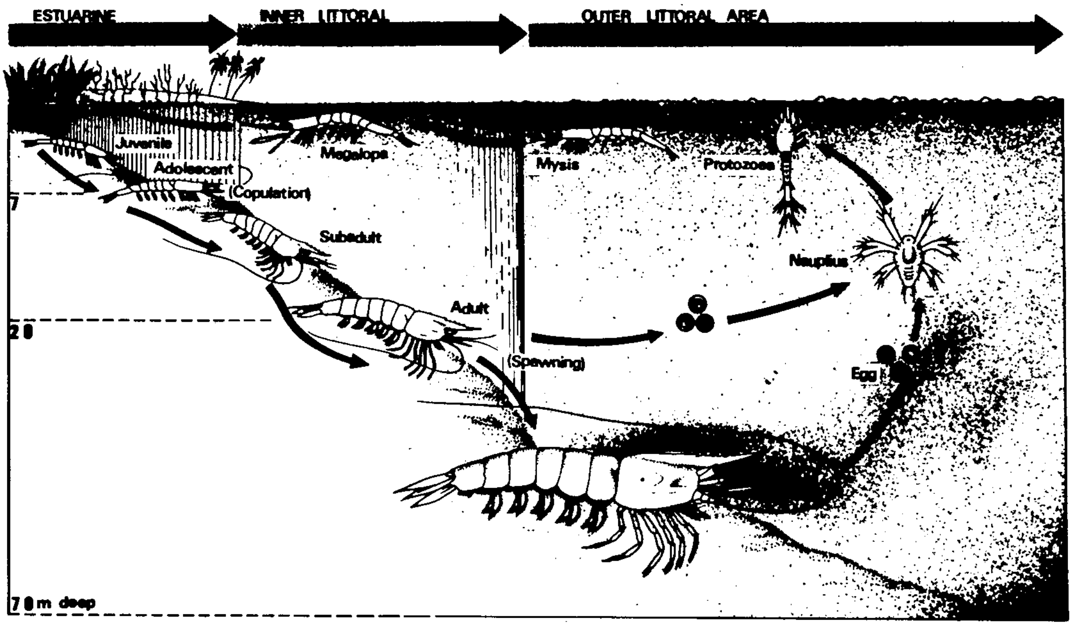


Fig. 122. The diagram of life history of the giant tiger prawn, *P. monodon.*

The spawning behavior was described and two peak seasons of spawning under natural conditions was mentioned, viz. February-March and October-November. However, another peak, viz. June-July was sometimes observed by the present author and witnessed by fishermen in various places. According to weather records, a dry season involves one spawning peak and wet season which has two peaks of rainfall sometimes has two spawning peaks, which suggests a close relationship between changes in rainfall and the occurrence of spawning. Further study on this aspect is merited.

During the growth study, it seemed to be impossible to depict normal growth of *P. monodon* while they were kept under laboratory conditions for a prolonged period due to environmental factors. To avoid this kind of defect, further experiments are necessary to establish the normal growth pattern, the increment per molt, as well as the molting interval.

The life span of male and female *P. monodon* is arbitrarily estimated as one and half and two years, respectively. This conclusion, however, will remain strickly theoretical until more evidence is collected, as there are insufficient data on this matter. In the near future, tagging experiments in the field and rearing experiments in captivity will be required to verify the life span.

The mechanism of inshore migration of larval *P. monodon* was depicted hypothetically, based on specimens collected and supported by information cited from other penaeids. Similarly to distinguish larval *P. monodon* from those of other *Penaeus* is still a problem to be solved. Also further study on the effects of salinity and temperature gradients as well as water movement on behavior is needed to elucidate the migration of *P. monodon* in detail.

XII. CONCLUSIONS AND RECOMMENDATIONS

As mentioned earlier, the spawning of the giant tiger prawn, *P. monodon,* takes place near the shore in fully saline water and in waters as deep as 70 m.

The larvae inhabit the offshore area, juveniles and adolescent the brackishwaters as their nursery ground, and subadult and adult inshore and offshore. Their life span may last from one and half to two years, the greater part being the nursery stage. Thus the protection of their delicate habitat is really important from the ecological point of view.

There have never been any cases of abundant catches of *P. monodon* at one time, although they are almost always sporadically caught in small number anywhere from brackishwater to deeper seawater in the Philippines. The species is never found schooling as detected by an echo sounder or from the air.

However, they maintain their population, in spite of locally heavy gathering of the fry both onshore and inshore, as well as commercial exploitation of the adults offshore.

One of the reasons that they maintain the population is probably their great fecundity viz. some 800 thousand eggs being shed per spawning female. Another reason might be attributed to the peculiar method of seeking protection viz. clinging to any object during postlarval stages, although they do not inhabit eelgrass or the *Zostera* zone where many postlarval *P. semisulcatus* and caridean shrimps are found as well as several other crustaceans and finfishes which act as competitors and predators.

To raise, protect and conserve the living resources of the giant tiger prawn for the future, the following practices are recommended.

1. Converting mangrove area into fishpond and human settlements should be minimized, because the area is usually effectively utilized by the megalopa, juveniles and subadults as their nursery ground.
2. Spreading of chemical e.g. gelar, rotenone, rosin amino acetate (Rada) for killing predators should be prohibited or regulated. When badly needed, the use of naturally and locally available materials e.g. tobacco leaves and tea seed cake are preferred within certain limits because these are harmless to prawns and shrimps. During the present survey, at the interior portion of the Batan Bay, there was heavy pollution of water with obnoxious substances draining directly to the creek from nearby fishponds during low tide which stunned or killed all larvae within the area.
3. Among the nursery grounds, fishing juveniles and adolescent *P. monodon* as well as other young penaeids should be minimized to conserve them as adults.
4. The fry collecting, handling and transporting techniques should be improved to increase survival. At present, survival during collection and stocking in the prawn ponds is more or less 60 % . As a matter of fact, when the fry concessionaire (middleman) buys the *P. monodon* fry from collectors, he asks them to give him 10 to 20 % extra amounts of fry to compensate for the mortality during fry handling and transporting.
5. At present, the price of *P. monodon* fry is decided by the fry concessionaire without any prior consent of fry collectors who are under his control and have no right to sell the fry to other concessionaires offering a higher price. A free market would provide better income for collectors who are generally poor, unlike the middleman.
6. When collectors are collecting fry along the sandy shore waters, after picking up "sugpo fry" they usually do not return the remaining organisms which compose many useful species of penaeid fry and fish larvae. It is recommended that they return these fry and larvae to raise fishstocks and to promote the conservation of nature.

7. On the other hand, other useful postlarval species, e.g. *P. semisulcatus, P. merguiensis* group, *P. japonicus* group, mostly dominant, should be stocked in brackish ponds, particularly during the dry season, because they are quite tolerable to high salinity up to 60 °/oo.
8. The waste from sugar factories is a serious pollutant in brackishwaters. During the present study, it was observed that there is no peak catch of sugpo fry when the waste was released at various places. Their drainage should be regulated by the National Pollution Control Committee of the Philippines.
9. At present, there is no reliable statistical data on the local, seasonal or annual production of the giant tiger prawn from brackishpond as well as offshore because of reluctance to declare yields for tax evasion. Through the Federation of Fishing Associations of the Philippines (FFAP), the local fishermen are asking the government to adopt a single fixed fee on the products to replace the existing numerous fees collected from fishermen, and are also seeking the elimination of the 4 % export tax imposed on prawns and the exemption from tariff duties plus compensating taxes, in addition to inspection fee, fishing ground fee, etc. (Philippine Daily Express, October 1979). To promote the prawn industry in the Philippines, reliable statistics on both offshore fishing and pond cultivations is highly recommended. Furthermore, record keeping of the number of sugpo fry collected in the field is advised to understand the relationship between fry and adult abundance and population dynamics. (In the case of milkfish fry production, it is annually recorded.)

The present author plans to undertake a genetic study on the giant tiger prawn. The prawn grows to a large size, particularly the females. However, the head portion, which is not suitable for human consumption, represents about 35 % of the total body weight, unlike *P. merguiensis* which possess a relatively small head portion (about 25 %). In addition, their study may be of value in the future for the production of more females than males because the former grows faster than the latter, thereby attaining a larger size.

So as to improve prawn palatability, the genetic study, e.g., cross breeding to attain a better strain, is a worthwhile experiment in the present author's opinion. This is presently being done in the field of animal husbandry on livestock and poultry.

Another idea may be the application of artificial fertilization to maximize utilization of dead and non-spawned spawners under laboratory conditions.

Prawn production will play an important role both in dollar earning and supply of animal protein to malnourished people among developing countries in the near future.

XIII. SUMMARY

The present study was carried out primarily by means of field surveys and secondarily by laboratory and pond experiments to reveal the fisheries biology of the giant tiger prawn, *Penaeus monodon* Fabricius, in the Philippines during the period from March 1975 to June 1980.

1. The giant tiger prawn is the largest penaeid prawn distributed in the Philippines and other Southeast Asian countries. So far, the largest female ever caught is 81 mm in carapace length (CL), 266 mm in body length or 262 g in body weight, while the largest male is 71 mm in CL. The giant tiger prawn is one of the most commercially important species in terms of selling value.

2. The maximum number of eggs shed at a time was 811,000 by a larger female. The larger the female, the greater number of eggs.
3. Spawning takes place at night, often between 2200 and 0300 hours, and lasts about two minutes under laboratory conditions. In their natural habitat, prawns spawn all year round, but there seems to be two peak spawning seasons in a year, viz. February-March or July, and October-November, based on the occurrence of spawners and postlarvae during these months.
4. Some spawners spawn for the first time at the mouth of bays where fully saline water conditions exist, but most often they spawn offshore in water up to 70 m deep, particularly during succeeding spawnings. Some may spawn four times within their life span.
5. The life history of *P. monodon* is classified into six phases: embryo, larva, juvenile, adolescent, subadult, and adult. The embryo, beginning with fertilization, is about 0.29 mm in diameter and takes about 12 hours to hatch. The larval stage, from hatching, consists of six nauplius, three protozoea, three mysis, and three or four megalopa substages with a total duration of about 15 days.

   The juvenile stage begins with the completion of the gill system, a carapace length of 2.2 to 11.0 mm, inhabiting brackishwater area. Megalopa and juvenile are collectively called postmysis, postlarva or fry for convenience.

   The adolescent stage, beginning with the stability of body proportion and the development of outer genitalia, still inhabits brackishwater area.

   The subadult, from the onset of sexual maturity, inhabits inshore areas. The first copulation occurs during this stage. The adult, from completion of sexual maturity, has a minimum size of 37 mm CL in male and 47 mm CL in female.
6. Their life span may be from one and half to two years, the female may be alive for longer period than the male. In general, the females are larger than males based on their catch composition.
7. *P. monodon* shows the fastest growth among *Penaeus* spp. in rearing ponds, followed by *P. indicus.*
8. The larvae mostly occur offshore, while during the megalopa and early juvenile stages, they migrate to shore waters, probably by the detection of salinity gradients in addition to the movement of the incoming flood tide. Eventually, they settle on their nursery grounds, e.g., interior portion of brackishwaters, upstream of big rivers as well as mangrove swamps, penetrating areas of almost 4 °/oo in salinity.
9. The postlarvae migrate mostly during nighttime on incoming tidal current to shore waters two to four hours before high tide. However, they do not stay for a long time (probably 10 days), estimated based on their size distribution.
10. The postlarval *P. monodon* appear all year round along the shore waters, with two peaks a year: July-August and November-December.
11. The adult prawn occurs all year round, with two peaks a year: March and September-November. They are nocturnal and are mostly caught during the new moon period.
12. The postlarval *P. monodon* have a great tolerance to changes in water temperature and salinity, withstanding ranges of 5 to 40 °C and 0 to 60 °/oo, respectively.
13. There has been no evidence of schooling of *P. monodon* either for copulation or spawning and no large concentrations were encountered during the present surveys and commercial operations.

14. There are presently five methods of commercial production of the giant tiger prawn, viz. the fry collection at shore waters or mangrove areas; artificial fry production in the hatcheries; inshore fisheries by fish corrals, baby trawlers and other fishing gear; offshore fisheries by commercial trawlers; and prawn cultivation in brackishwater ponds. The last is the most promising industry, supported mainly by the artificial fry production, and in the near future may be the most widely used method of the production.
15. For the conservation of the nursery grounds and for increasing production of the giant tiger prawn, the following are proposed:
    i) Avoid conversion of nursery grounds (brackishwater areas) into fishponds or human settlement areas.
    ii) Ban spreading out of chemicals for killing predators in fishponds and nursery grounds.
    iii) Introduce postlarval *P. indicus* as well as *P. merguiensis* into prawn ponds in addition to *P. monodon.*
    iv) Keep statistical data on the population of fry and adults of *P. monodon* and other penaeids in relation to their habitat and growth stages.
    v) Artificial fertilization and genetic study might be necessary in the future to utilize dead spawners or to produce more suitable prawns.

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