NOTES ON THE BIOLOGY AND AQUACULTURE OF *SCYLLA SERRATA* (F.) DE HAAN*

by

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I. INTRODUCTION

A. Taxonomy:

Scylla serrata, commonly called "alimango" in both the Tagalog and Visayan regions, belongs to the Phylum Arthropoda, Class Crustacea, Order Decapoda, Family Portunidae and Genus Scylla.

Estampador (1949) described the genus Scylla as having an almost smooth-surfaced, broad and transverse carapace. The front part is continuous with the inner supraorbital angles which are cut into 4 teeth. Antero-lateral borders oblique and arched, longer than postero-lateral, cut into 9-teeth of nearly equal size. Paired chelipeds massive, longer and bigger than any of other legs arm, wrist and hand with definitely positioned spines; hands deep and full. Genus Scylla consists of three species and one variety: Scylla serrata, S. oceanica, S. tranquebarica and S. serrata var. paramamosain respectively (Estampador, 1949).

The following is the diagnosis for Scylla serrata as taken after Estampador, (1969).

Scylla serrata (Forsskal): Carapace, about two-thirds or a little less, as long as broad, practically smooth, except for a faint granular ridge running obliquely inwards across either branchial region from last spine of antero lateral border. Front cut into four lobes or bluntish teeth of about equal size and prominence. Antero-lateral border cut into nine sharply accuminate teeth of about equal size. Posterior border forming a curve with postero-lateral border, points of junction sometimes slightly slackened. Chelipeds not quite twice length of carapace in adult male, but shorter than in female and young male. Hands with three tubercles, one being in front of apex of wrist joint, other two being side by side behind finger joint, outer of these two sometimes obsolescent. Legs unarmed, dactyli strongly sulcated, their anterior and posterior margins, fringed with brushlike hairs. Abdomen of male broadly triangular; oval in young females but becomes more circular in outline in big females.

Sexual dimorphism in S. serrata is apparent in specific body parts. The chelipeds of the male are more massive than those of the female. The female's body is generally longer and wider than that of the male. A male or female may, however, exhibit "right-handedness" or "left-handedness" where the right or the left cheliped is bigger than the other.

For identification of other species the following key developed by Estampador (1949) is useful:

a1. General ground color greenish, grayish green or olive-green; sometimes with shades of purplish or reddish generally on chelipeds and legs. Contour of body not very distinctly convex; H-like mark on carapace relatively deep.

b1. Carapace and legs, including chelipeds, predominantly or grayish green; large polygonal pigmented areas present on all legs including chelipeds, and on abdomen in females; chelipeds in adult not more than twice the length of carapace — S. oceanica.

b2. Carapace olive-green, purplish with greenish tint, or purplish brown; large polygonal pigmented areas distinct only on last legs, and a few may be seen on the abdomen in females; chelipeds often reddish or purplish, length in adult males more than twice the length of carapace . . . S. tranquebarica.

a2. General ground color deep rusty-brown, purplish brown to light brownish gray; dorsal contour of body more distinctly convex; H-like figure on carapace relatively less deep.

b1. Color varying from deep rusty to the purplish brown; outer spine on base of fingers obsolescent, becoming vestigial on bigger specimens; frontal teeth about same level . . . S. serrata.

b2. Color generally brownish gray with patches of bluish at joints of legs and chelipeds; median pair of frontal teeth slightly produced anteriorly; outer spine on base of fingers unequal but not obsolescent. . . S. serrata var. paramamosain.

B. Zoogeography:

S. serrata has a fairly wide distribution being found in Africa, India, Ceylon, Australia, Malaysia, Indonesia, Palaw, Thailand, Philippines, Fiji, and Hawaii. Its wide distribution can be generalized in the coastal areas of the Indo-Pacific region especially those in the Philippines characterized by extensive mangrove swamps and brackish waters.

C. Economic Importance and Fisheries Aspects:

'Alimango' is a highly esteemed table delicacy here in our country with soaring prices especially during the holidays. In Bangkok, 1 kg of crabs of various sizes would cost 10-15 baht (US $ .50-75 = ₱4-6) and 1 kg of ovigerous females would cost 20-25 baht (US $ 1-1.25 = ₱7-8) (Varikul, et. al. 1973). Current prices gathered during a recent (April 1977) survey of Panay, Philippines are ₱8-15 for 1 kg of crabs of various sizes and ovigerous females costs ₱5-8 each.

In Penang, Malaysia, 1 kg of male crabs would cost M $ 1.30 while 1 kg of females with well developed ovaries would cost M $ 2.40. The latter are better relished by costumers (Ong, 1964).

The crab fishing industry is quite extensive here in the Philippines (Arriola, 1940). 'Alimango' is caught in commercial quantities by means of a trap (bintol) hook or panukot, sakag or scissor net and gill nets (Arriola, 1940; Pagcatipunan 1973). Berried females are sometimes caught in fish traps lining the outlets of estuarine waters together with other species. These can also be caught by using a bamboo trap called panggal in

Visayan. Juveniles are caught barehanded or with sticks by children and adults in swampy places during the times that these begin climbing upstream. The small larvae are sometimes carried by incoming tide and enter fishponds which perhaps explains the presence of crabs in ponds in spite of no intentional stocking on part of the owner.

It might be safe to say that the market for 'alimango' is insatiable here and abroad. In Ponape, for example, in a recent mangrove crab fishery report (Perrine, personal communication, (1977a) it was mentioned that there are at least 7 local restaurants and hotels that serve crabs and have done so for the past years. One called Village Hotel uses 250 lbs of 'alimango' per month. This figure according to Perrine (1977b) reflects scarcity of supply.

With regards to exported crabs, customers in places like Ponape prefer crabs from the Philippines because these are pond raised and the flavor is better than that of crabs foraging for their food in the wild (Perrine, personal communication, 1977c). In Camarines Norte, Philippines, crab catch are sent as far as Manila where these are priced highly (Pagcatipunan, 1973).

The biological aspects of S. serrata as a species are not well explored. Cultivation techniques are as yet poor and undeveloped perhaps due to weak knowledge on the species biology. It is very obvious that there is so much to be done on these problems.

II. BIOLOGY

A. Life Cycle:

Though only very few have studied some of the biological aspects of 'alimango' (Arriola, 1940; Estampador, 1949 and 1969; Escritor, 1973; Pagcatipunan, 1973' Varikul, et al., 1973, E. Laviña and A. Buling (unpublished paper, 1976), the life cycle of this species is generally known. This is schematically presented in Figure 1.

Part of the species life cycle is spent in sea water and part of it in estuarine or brackish water. Technically, this species is catadromous.

1. The Oceanic Phase

a. Spawner

It has been reported by fishpond owners and fishermen in Southern Negros and Panay Islands that they have observed berried females climbing over their fishpond dikes. According to their reports, these were migrating seaward. Some APDEM II* participants who are raising crabs confirmed these observations. These observations suggest that sexual activities like courtship and mating occurred in the brackish environment. Later spawning followed and the egg got attached to the pleopods of the female. Migration to saline waters must have followed shortly after the spawning activity. However, if the spawner failed to migrate from the pond, this would hatch its eggs which exhibited very low survival rates. This could probably be due to unsuitable salinity and temperature levels. In the Philippines the 'alimango' is said to spawn throughout the year with a peak season from May to September (Pagcatipunan, 1973).

Reports of fishermen in Hawaii suggests that S. serrata spawns between early May and late October in the island at an average oceanic temperature of 25.8°C (Brick 1973). In Thailand, Varikul et al (1970) reported that spawning occurred during their warmest months (29°C).

Brick (1973) reported that a berried crab caught in Kaneohe Bay that hatched in the laboratory pond (at 30 feet depth) was found 40 days later to be fully berried again in the same intermolt period. Others like Bardach, et. al (1972); Overstrut and Cook (1972) and Ong Kah Sin (1973) reported the same observation in other brachyurans. These reports agree with our observations of certain rematuration cases of spent spawners kept in a rematuration tank at an ambient salinity from 31-34‰.

The reproductive potential of S. serrata is very high. Arriola (1940) reported about 2 million eggs per spawner; Ong (1966) reported

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* APDEM means Aquabusiness Project Development and Management. APDEM II was a seminar-workshop held in the College of Business Administration at the U.P. Diliman, Q.C. from July 28 to August 16, 1980.

the same number to be released by a captive spawner but only 1/3 of which got successfully attached to the pleopods. In addition, Ong observed a spawner from the wild to have spawned 3 times in 5 months while kept under laboratory pond rearing conditions. This was observed to occur without molting and mating on part of the captive spawner.

Spawners collected from the wild were used for the various experiments especially on larval rearing and on rematuration. These were disinfected with formalin (50 ppm) for 20 minutes upon arrival in the station before stocking in aerated half-ton spawning tanks. These tanks are usually covered with black cloth to limit illumination. It has been observed that light intensity influences the behavior of spawners and maintained in captivity. Although the mechanism is as yet unknown this could be assumed to be related to the response of wild spawners to the lunar cycle. The incubation period varied according to the developmental stages of the spawners as they came in from the wild. A yellow-berried female would take from 8 days to 2 weeks incubation period depending on the suitability of laboratory conditions provided. One can fairly judge the hatching day by looking at the egg color.

The hatching rates of these spawners varied from 70-95% of the total potential. Variations in the rates were due to handling stress during capture, transport and laboratory handling.

It has been observed that it is easier to collect spawners during 2-3 days before and after the new moon and the full moon. The lunar cycle's definite influence on the migration behavior of spawners and spawning itself is still unknown.

b. Larval Development

There are five zoeal stages followed by one megalopal stage prior to the crab stages (Figure 2). Molting of the zoea to megalopa stage takes place by a split at the dorsal boundary between the cephalothorax and the abdomen. Furthermore, it takes about 18 days for zoea to reach the megalopa stage at 31 + 2 ppt of seawater. It would take another 2 weeks at same salinity levels for megalopae to reach the crab stage but at lowered salinities (21-27 ppt) this could be shortened by 1 week. Hastened development at lower salinities would suggest the direction of migration of the juveniles towards the brackish waters.

All the zoeal stages swims by means of the exopodites of the first and second pairs of maxillipeds with the dorsal spine usually directed anteriorly and the rostral spine ventrally. At the megalopa stage, this organism becomes benthic but exhibits occasional swimming in a circling motion using the 5 pairs of pleopods which become functional this time.

The terminal segments of the fifth pair of periopods become flat and functional as natatory legs in the first crab stage. At this stage, the animal looks like a miniature adult. The mean carapace width of the first crab instar is 3.20 mm. Ong (1966) reported a figure of 3.40 mm.

1. Food habits under artificial conditions

One of the main considerations in hatchery attempts on Scylla serrata (Forsskal) de Haan is the kind of food suitable for larval development. In close grip with the problem of suitability is the basic question of acceptability of certain feeds by the organism.

The feed combination of Artemia, Brachionus and Chlorella was used during the larval rearing of Scylla serrata in the laboratory. Although survival rate was very low, the crab stages were reached in 23-30 days range. This feed combination was used throughout the zoeal stages with progressive increase in the feeding rate as metamorphosis proceeded. The initial feeding rates used were approximately: Artemia at 5-10 individuals per ml. of rearing medium, Brachionus plicatilis at 3-7 individuals per ml and Chlorella at 100,000-500,000 cells per ml.

Progressively also, the sizes of the Artemia used as larval feed were adjusted according to the size increases of the larvae. Megalopae were observed to ably tackle Artemia adults, live or frozen. Early crab instars fed well on frozen Artemia adults. When using frozen Artemia adults as food, these were deposited into the screen (5 mm mesh) which were placed in strategic sites inside the rearing tanks. The nylon screen served as clinging material for the megalopae which exhibited such behavior indicative of the settling behavior of crab instars.

Other forms of feeds, singly or in combinations, were tested in order to know what are acceptable by S. serrata larvae and whether such would allow for metamorphosis. These tests were conducted during the months of July and August 1977.

In three triplicated runs, 39 1.5 liter plastic jars were stocked with newly-hatched S. serrata larvae at 10 larvae per liter. Table 1 a. shows a list of the test feeding formulae in this experiment. The feeding rates are also summarized in same table.

Larval count was done daily before feeding time. One fourth of the water volume was drained out and the test feed or feed combination used was administered. Water volume was then adjusted to make one liter. Aeration was continuous which allowed for slight water turbulence throughout the study period of 10 days for each run. Observations in these small containers were limited to 10 days because handling of larvae by droppers during counting imposed too much stress on them. As soon as the larvae passed the second zoeal stage the experiment was terminated, the remaining live larvae were transferred to the bigger rearing tanks. Newly-hatched larvae were procured to replicate the experiment.

Metamorphosis into the second zoeal stage was used as a measure of the suitability of the food being tested, at least, for the molting from first to second zoea. Microscopic examination of the larvae was done to observe whether their gut contained the test food or not. Presence of the test food in the gut was used as measure of its acceptability by the larvae.

Routine readings of salinity and temperature were made daily.

RESULTS AND DISCUSSION

Microscopic examination of the gut of the larvae revealed acceptance of most of the test feed and feed combinations.

Chaetoceros used singly allowed very few of the S. serrata larvae to survive up to the 8th rearing day. This observation implies that Chaetoceros sp. a diatom, is to some extent usable as larval food of S. serrata. When paired with Artemia salina nauplii, molting of zoea 1 to zoea 2 occurred in 4 days as normally expected in S. serrata development. This observation implies that a combination of both phyto- and zoo-feed is necessary for larval metamorphosis in S. serrata.

One main disadvantage of Chaetoceros as food in a plastic jar culture system is that, this diatom, as observed in the experiment exhibited speedy sedimentation causing the accumulation of a sticky material on the bottom of the rearing containers. During larval counts made, many larvae were recovered from this settled material which probably failed to free themselves when caught. Larvae of S. serrata are characteristically planktonic during their early stages, however, at certain times these larvae would glide down with the water current (caused by aeration) and shortly, settle themselves in the bottom of the plastic jars. During this time, some perhaps failed to disentangle themselves from the sticky sediments of settled Chaetoceros.

This observation was more apparent in molting larvae. Being weak during and after the process, these larvae were observed to settle more often on the bottom than the unmolting ones. It was not seldom that some incompletely molting larvae were recovered from the same sediments already described. Protozoans and bacteria were abundant in the containers of the Chaetoceros-fed larvae as soon as the sticky sediments thickened. Chaetoceros as food then could also be a pollutant. The feeding rate may have been a variable in itself but this could well be treated in another investigation. The design of the rearing container used may also play an important role. The observations on the presence of protozoans and bacteria were incidental to the experiment.

Chlorella as algal food has been mentioned as a green medium that acts as water quality controller (Reeve, 1963). The universal status of this algal food includes its common use as food for Brachionus culture. It is known that the maintenance of Chlorella culture is imperative to Brachionus culture. This was also one main reason for combining Brachionus with Chlorella in this study in order to keep the rotifer alive and therefore, this would be kept in circulation. However, Chlorella used as single food, although accepted by the larvae allowed survival of a few larvae to the 5th day of rearing. No metamorphosis was observed. Brachionus combined with Chlorella allowed longer larval survival. In most of these, it was observed especially on the third to the fifth day that the protozoan populations were very high. The presence of these microorganisms were observed during the microscopic examinations made of the larval gut. The observations being incidentally important are mentioned here.

Egg powder was also observed to be accepted as revealed by microscopic examination of the gut of the larvae. However, the onset of protozoan populations in rearing conditions with egg powder was observed as early as the first day of the experiment, this again was seen during the microscopic examinations of the gut.

Egg powder combined with Chaetoceros, also caused the accumulation of coats of bubbles on the surface of the water medium. Often, larvae were recovered entangled in these bubbles. The population of S. serrata larvae fed with egg powder and Chaetoceros all died on the 3rd day of rearing.

Scylla serrata larvae were observed to accept squid meal powder (100 mu). There was apparently no digestion that occurred because dead larvae were recovered with the squid meal particles intact inside the gut. Some larvae in the containers with this powder in combination with Chaetoceros survived up to the 4th day of rearing. No molting was observed to occur.

Spirulina as food for S. serrata larvae exhibited the same disadvantage as egg powder - the accumulation of bubble coats on the top of the rearing medium. Survival was observed up to the third and fourth days for very few larvae. It could not be determined whether digestion of Spirulina occurred or not although its presence in the gut was clearly seen. The gut appeared green when full of Spirulina.

Artemia salina administered as freshly hatched nauplii to S. serrata larvae offered many advantages. One advantage is its characteristic of being phototactic (strain used was positively phototactic - S.F. Calif.). S. serrata larvae exhibited the same behavior and so the problem of food availability as well as proximity is solved. This is especially important in a flat bottom culture system.

In terms of size relationship between A. salina (freshly hatched) nauplii and crab zoeae. Figure 3 shows very clearly that an A. salina nauplius is really quite big as a motile food. However, the mandibular equipment of S. serrata larvae are quite capable of handling the brine shrimp. Freshly-hatched nauplii (S.F. Calif. brand) range in size from 281 to 470 micra (body length). Freshly-hatched crab larvae range in size from 600 to 1100 micra (Spawner: Carapace length = 75.1 mm, Carapace breadth = 105.5 mm, Body weight = 252 g). Decapsulated cysts of Artemia would be a promising food for crab larvae, based on the observations of zoeal sizes. These range in diameter from .1500 to .2275 micra.

Artemia salina as an obligate filter-feeder (Sorgeloos, 1978 personal communication, Phil.) can not be discriminate of the particles that pass through its thoraco-filtration system. This means that the metabolites of crab larvae also pass through the same filtration system and are, perhaps, utilized as food. Much more, the brine shrimp nauplii fed to the larvae were not fed anything. This was intentional in order to stunt their growth and therefore, they would not speedily outgrow the larvae.

It has to be taken into consideration though that any other material added to the rearing medium in addition to the reared organism becomes a competitor in terms of space and nutrients (organic and inorganic) in the case of live materials. Certain physico-chemical factors also come into the scene in relation to these.

CONCLUSION

Observations lead to the conclusion that the combinations of A. salina + Brachionus + Chlorella and A. salina + Brachionus + Chaetoceros are the best so far.

The size relationship between food and crab larvae showed up to be a main problem. This was especially apparent in freshly-hatched Artemia nauplii as food for crab larvae.

Whether the food given is alive or in dead form this has to be in suspension in order to be available to the larvae.

All test feed and feed combinations were observed to be potential sources of pollutants. These were exhibited in different degrees by the different feeds.

A student Newman-Keuls test was applied on the experimental results. No significance was found between formulas i and j, n and f, f and a, h and k and c, m and d (see Table 1 b)

RECOMMENDATION

A feed acceptability test on other cheaper forms of feed should be made.

The rearing or larviculture system's engineering has to be improved taking into consideration the following problems that were noted in this study:

1. sedimentation
2. water circulation
3. food availability, that is, proximity of food to the larvae, not just presence of food
4. evaporation in small containers that resulted in increased salinity readings

Other problems have to be considered also like O_2 level maintenance and feeding rates in relation to the above list.

Size relationships between food and the larvae have to be reexamined.

2. Stocking Density:

Experiments on stocking density of S. serrata crab larvae showed highest survival at the rate of 30 larvae per 500 ml of rearing medium (See Figure 4). In the Naikai Experimental Station in Japan, the stocking rate employed is 30-50 larvae/liter for the species Portunus trituberculatus. This same species is cultured in big scale by the Hiroshima Prefecture Fisheries Experimental Station and the stocking rate is about 25 larvae/liter.

With Portunus pelagicus I found the stocking rate of 50 larvae per liter of rearing medium to show the highest survival rate.

3. Problems During Rearing:

S. serrata as a species is characteristically cannibalistic even at the larval stages. This agonistic behavior posed a problem in the larval rearing experiments. Ong Kah Sin (1964) kept his larvae singly from the megalops stage onwards. According to this author, cannibalism was one main cause of high mortalities in the rearing experiments.

Cannibalism was exhibited by the zoea themselves. In many instances, these were collected in clumps as early as the 2nd day of rearing where each larva was biting the other.

Another problem during rearing is the apparent weakening of the larvae during the premolting days which would render them prone to infection by certain pathogens. Of the first batch to attack are the protozoans and bacteria. In the more advanced stages of infection observed, the fungus Lagenidium was occasionally found. Robert Brick (1973) used water medium treated with 40 ppm Penicillin-G and 10 ppm Polymyxin-B sulfate for his rearing experiments.

4. Tolerance to Certain Physico-Chemical Parameters:

The effects of salinity, temperature and their combined effects under laboratory-controlled conditions have been described for the larvae of several additional species of crabs (Costlow, Bookhout and Monroe, 1960, 1962, 1966). In a follow-up study by Costlow (1967) on the combined effects of salinity and temperature, he found out that at 25°and 30°C, in salinities of 10 to 40 ppt, survival ranged from 78.9 to 100 percent while at 20°C survival ranged from 70 to 90 percent in all salinities except 5 ppt. At 15°C, the most pronounced effect was extension of the duration of the megalops stages. At the same temperature, he observed that the length of megalops duration was further increased as the salinity was increased from 20 to 40 ppt.

In a separate experiment, lowering of the salinity of the larval rearing medium was tried starting from 25 ppt down to 5 ppt with a difference of 3 ppt in between levels and where each level is maintained with a control. At day 4 when rearing group six (5 containers, 30 larvae) was changed to 16 ppt; it showed the highest survival, about 45% which meant to be at 19 ppt.

Temperature range during this experiment was from 25-27°C. Part of the cause of mortalities must have been the handling stress imposed on the larvae. The numbers gathered during monitoring were too low to be significant for statistical analysis.

The rate of development of larvae of certain brachyuran species is affected by temperature as found under controlled rearing conditions. In general, a reduction of 10 degrees from 30 to 20°C would double the time required for complete larval development. Chamberlain (1962) reported an increase in the duration of the four zoeal stages of Rhithropanopeus harrisii at 15°C and 24°C. On the other hand, the length of zoeal life of Sesarma cinereum was prolonged by a reduction in salinity. The same trend was exhibited by the megalops but the results were not as definite and there was overlapping in the time required for development of the megalops at different salinities. (Costlow, Bookhout and Monroe, 1960).

The relationships of these two factors, salinity and temperature singly and combined, in relation to larval development and survival are virgin fields of investigations in 'alimango'.

2. Estuarine Phase

a. Growth

Ecdysis or molting is the only way by which hardshelled crustaceans like crabs can grow. This is exhibited periodically by the animal.

In different runs, a total of 150 crabs of different sizes were maintained in land-based tanks. These were observed to take note of growth in terms of increases in the carapace length, carapace width and body weight increment.

Table 2 shows the body size increments of crabs after their first molt in captivity. The average increase in carapace length from 35 specimens that molted was 8.48 mm, average carapace breadth was 11.28, average increase in body weight was 25 grams in an average period of 15 days. The average growth increment in a fenced pond is 13.15 mm C.L. and in a nursery pond (Barican) is 12.87 mm C.L. in a period of 126 and 183 days, respectively. (Escritor, 1973).

The total food given in the fenced pond was 89 kg and it was reported nil by Escritor (1973) in the Barican Nursery Pond. In these experiments, conducted here at SEAFDEC, AQD the intensive techniques employed in artificial propagation include the following: 1) water quality management 2) shelter or refuge system 3) regular feeding schedule at continuously adjusted areas.

In our artificial propagation experiments the tanks used were one-tonners. The sand-filtered sea water (30-34‰) was changed every other day or, as necessary, where all pollutants and fe-es were drained out.

The water depth was maintained at 150 mm about the height of the refuge system. The refuge-shelter system consisted of hollow blocks (See Figure 6). With this system, we were able to employ a stocking rate of 33 crabs/2m^2 for heterogenous stocking type (60-100 mm CB). For crabs with approximately uniform measurements (ex. 80 mm CB) the rate could go as high as 50 crabs/2 m^2. With a refuge system the biweekly growth increment of crabs in the broodstock was 80-100% higher than without. Feeding rates were established and ranged from 3% to 5% of the total body weight.

b. Maturation

Arriola (1940) observed 2 crabs; one became sexually mature in 142 days (12 molts) the other in 156 days (15 molts). Originally these were 4.9 x 8.5 mm and 5.4 x 9.3 mm. According to this author, it would take about 5 months for a crab to attain sexual maturity. The first mating females observed by Ong Kah Sin (1966) were three 16th crab instar specimens measuring 114.2, 109.5 and 99.1 mm in carapace width or breadth. The average size of sexually mature male (16th crab instar) was 99.7 mm. In our broodstock where artificial propagation techniques were employed, mating couples measuring 62-105 mm CB were observed. Where mating was induced by ablation of one eyestalk, the range was from 84-126 mm CB. However, the procedure if timely employed could result in hastened reactions like shortened premolting period in order for the female to accomplish the pre-copulatory molt quickly. In the average, the mating duration is shorter in induced matings by ablation.

An experiment on gonadal maturation of freshly-copulated females of S. serrata at different salinities was conducted. Freshly copulated females were collected from the broodstock and subjected to rearing water media of different salinities namely: 22, 26, 28 and 32‰. After 15 days, comparative dissections were made to examine the extent of gonadal development of these crabs. Egg smears were examined and the eggs measured. Gonadal development was fastest at 26‰ in which eggs measured .22 mm (ave.) across. This was followed by 22‰ with eggs measuring .19 mm. (ave.). Egg color was, however, brightest orange at 28‰ but these measured only .14 mm. These results still have to duplicated. As they are, these results suggest that gonadal maturation until spawning occurs in brackish estuarine waters.

c. Ecdysis, courtship and mating behavior of Scylla serrata (F.) de Haan in captivity

1. Ecdysis

Ecdysis or the shedding off of the exoskeleton is characteristic of arthropods in general. Otherwise termed molting, ecdysis is the process by which hard-shelled crustaceans like crabs can increase in size. Molting is also significant in relation to the regeneration of injured body parts and mating in mud crabs. A female mud crab has to undergo a molt prior to actual copulation by a male mud crab. Of the few works on some aspects of the general biology of Scylla serrata (Arriola, 1940; Ong Kah Sin, 1966; Pagcatipunan, 1973) not one describes the molting repertoire of the species.

Part I of this section of the paper aims to give a detailed description of the molting behavior as exhibited by Scylla serrata reared under laboratory conditions. This report is based on 57 specimens observed to have molted in captivity.

DESCRIPTION OF THE MOLTING PROCESS

Two to three days before molting, a crab would exhibit very sluggish behavior and would appear to refuse food. Feeding activity eventually stopped 4 to 6 hours before actual molting and the crab would move to a less-frequented area of the tank. In many instances, a crab ready to molt would settle in a well-aerated area.

Upon settling in the "safe" area the crab showed a peculiar behavior that may be described as uneasiness. The crab moved sideways but covered only small distances. When stationary on a spot it would scrape the tank floor with its legs and chelipeds as if in an excited frenzy. This behavior was also exhibited in crabs that molted in the small glass aquaria where coarse sand was provided as substratum. These displays continued for 30 minutes after which the crab stopped still. After a few minutes, the first abdominal segment showed a visible gap from where this met the carapace and the crab raised its chelipeds up making a 30° angled position. The sideways and scraping movements resumed for another 30 minutes during which the new first postero-lateral spines came out and the posterior abdominal gap increased in width. As the next two new postero-lateral spines came out the crab raised its chelipeds again in a 30° angled position this time wriggling them sideways. When the crab settled down again the chelipeds were stretched forward in an almost perpendicular position in relation to the body. Simultaneously, the eyes slid off leaving the old exo-coating transparent and more lateral body spines were released. The withdrawal of the new spines became faster accompanied by apparent wriggling of the hind legs. The whole body was shaking as the old gills were molted. The most posterior natatory legs were drawn out first followed by the rest of walking legs going forward. The chelipeds were the last to come out and appeared to be the most complicated in the process. Whenever a segmented portion of the chelipeds was released during molting, the crab stayed motionless as if resting before the drawing activity was resumed.

The whole process of molting would take an average of 2 hours and 22 minutes and would usually be concluded by the shaking off of the old exoskeleton. The new individual that came out appeared very wrinkled when taken out of the water. A newly molted crab may take in as much as 20 to 30 gms. of water following ecdysis. Complete body hardness was regained in 72 hours after molting.

BODY SIZE INCREMENTS FOLLOWING ECDYSIS

Table 2 shows the increase in body size of 57 crabs after their first molt in captivity.

The average increase in body weight after a molt is 24.5 grams in an average period of 16 days. In some cases, the body weight decreases after a molting activity. This would suggest that body weight is a less reliable factor for growth measurements after ecdysis. Regardless of an increase or decrease in weight, a molted crab exhibits apparent increase in carapace span and length.

Table 3 shows the measurements made of a crab after molting. The complete expansion of the carapace length was accomplished in 15 minutes, however, water intake was continuous until complete hardness of the new exoskeleton was gained.

2. Courtship and Mating

Part II of this section describes the courtship and mating behavior of Scylla serrata reared in the laboratory. Observations were made on 25 pairs of crabs that mated in captivity. These were maintained in 1-ton wooden tanks provided with a refuge system composed of hollow blocks. Aeration was moderate and continuous, water salinity was ambient from 30-34 ppt and temperature ranged from 23-26°C.

Courtship

Part of the courtship in Scylla was the repertoire in which a sexually ready male would chase a female around. This was observed to be more frequent at night. The chase seemed peculiar because whenever the female stopped moving away the male stopped too. There was apparent discontinuity in the chase activity during the early stage of courtship. The time duration the chase varied from 30 min. to 1 hour and 20 min. The conclusion of the chase activity was characterized by the female allowing the male to position itself face to face with it. When positioned so, there was very rapid movement of the mouthparts and the antennules. The chelipeds of both male and female crabs were stationary and were placed close to their bodies. This display lasted for 30 seconds to one minute at most after which the female stayed passively unmoving and allowed the male to climb onto its back. The male huglocked the female's body with its first pair of walking legs and carried her around. This embrace would last from 2 days for the shortest duration observed to 7 days in the longest duration observed.

A variation of the mounting behavior of the male was also observed in many instances. The male would climb on the side of the tank bracing itself against the refuge blocks for support. In this position it readied itself for a fall. As the female passed by the male would fall onto its back and hug-lock it as described earlier. In some cases where the female was not receptive, attempts like this ended in fights which resulted to casualties in the form of body injuries.

During the amplexus period feeding was negligible in both male and female. In some couples observed food was completely refused especially when the duration of the amplexus was short.

The Pre-copulatory Molt

Prior to copulation wherein the female was ready to molt, the male released it. The female stayed passive beside or in front of the male and underwent ecdysis. During such activity of the female, the male opened its abdominal flap and positioned the 2 gonopodia or genital organs in an almost perpendicular angle in relation to the body.

Mating

After the female's pre-copulatory molt which rendered it soft and helpless, the male turned the female on its back. The male placed its belly face to face with the belly of the female. During this repertoire the male raised its body slightly using the walking legs. The chelipeds, and the whole body of the male crab were used to nudge open the abdominal flap of the female. When opened already, the male inserted its gonopodia into the genital openings of the female crab. Upon complete penetration the embrace became permanent in which the interlacing of the legs of the male and the female crabs were alternate. In some cases though, the legs of the newly molted female remained passive in position proximal to its body. Thus, the female was carried around by the male while holding its body up with the use of the first and/or second pair of walking legs making an allowance of .25 to .5 inch between the soft carapace of the female and the tank floor. Although most of the movements of couples observed were exhibited in one place, the mating pairs would move away from bright light and from invaders. The latter were other crabs in the tank or even the shadow of the observer. The female crab exhibited leg movements sometimes.

Table 4 is a list of pairs of mud crabs that copulated in captivity.

Figure 9 is a drawing copied from a photograph of a mating couple of Scylla serrata (F.) de Haan.

ACKNOWLEDGMENT

My special thanks to Miss Amalia S. Buling for assisting me in this behavioral study.

III. AQUACULTURE: APPLIED ASPECTS

A. Pond Rearing

Very few techniques are being employed by Panay fishpond owners who culture Scylla serrata. (Author's ocular survey of Panay, 1977). Some of these are bamboo fencing of the ponds, use of shallow ponds (not more than 1 meter deep) and use of mangrove trees as shelter system for crabs. Feeding is intermittent or none at all so that the crabs have to forage for food. This is observed to be one main cause of mortality in most ponds stocked with crabs. The lack of food encourages, much more, the cannibalistic behavior of this species. It is usually the subordinates and the smaller ones that are cannibalized.

In a fenced pond the stocking rate employed could be 1 crab/0.41 m^2 and the average growth increment would be 13.15 mm CL and 17.23 mm CB for a period of 126 days. (Escritor, 1973). At the Bangehan Fisheries in Chantaburi, Thailand, the stocking rate was 4000 crabs/.4 ha and survival rates vary from 71 to 87% at harvest time (Varikul, et. al 1973).

In Camarines Norte, the 'alimango' is used as a subsidiary crop to milkfish (bangos). (Pagcatipunan, 1973). In Panay Island only undeveloped ponds are stocked with these crabs. Some fishpond owners practically despise this species because this would burrow into dikes and destroy them.

B. Crab Fattening in Ponds: Proposed Techniques

For a good and easily manageable start - 250 to 500 m^2.

One may have 2 options:

(1) cemented dikes
(2) earthen dikes with bamboo slat fencing

If taking option a: may use the sides of the dikes with built-in refuge system. Orient the ready-made burrows in a zig-zag manner to avoid proximity between crabs. The maximum height allowable for use must not exceed 1/3 of the total dike height.

If taking option b the refuge system, which may consist of hollow blocks or bamboo nodes, can be arranged in rows on the substratum. The same arrangement may hold true for option a.

Slat fencing — Tie together the bamboo slats with mangrove vine or small abaca rope or nylon rope whichever is preferred. The first tie should not be less than 6 inches away from the level of earth dike into which the fence has been driven. The second tie and succeeding ties thereafter must not be less than 6 inches apart. The fencing must be set at an angle of 35-40° in relation to the pond's substratum. The distance between the bamboo slats may depend on the size of initial stocks. However, a distance of .25 to .5 inch between the slats may be safe enough to avoid migration of stocks. For convenience a "door" may be constructed at strategic points of the slat fence but this must be of the same material as the fence. In the same manner as the fence, the door(s) must not allow migration of stocks.

Refuge system - is compulsory to assure better returns from initial stocks. There are at least two (2) options:

a. bamboo nodes
b. hollow blocks

Figure 10 shows the sthematic diagram of these types of refuge system.

As to sizes of compartments provided, allow for whatever size of stock you want to attain in your fattening process.

"Breathing mounds" - During occasions of very low dissolved oxygen, crabs are known to climb onto mounds or stumps in the pond. Such mounds may be provided and may be arranged strategically inside the pond. Two opposite sides of the mounds may contain built-in units of the refuge system in zig-zag manner to reduce the proximity of crab to crab, also to allow for paths on which the climbing crabs can safely pass.

Water exchange - ideally must be flow through. Although known to be very sturdy, crabs like alimango is still sensitive, just like prawns, to D.O., and pH fluctuations.

Salinity - Crab fattening would be most ideal in levels from 22 to 26 ppt., 26 being the optimum level.

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Table 1a. List of Test Feeding Formulae

Formulae	Food	Rate
a. Chaetoceros	Chaetoceros (live)	100,000-500,000 + cells/ml
b. Artemia salina nauplii (freshly-hatched)	A. salina nauplii (live)	5-10 indl's/ml
c. Chaetoceros + A. salina nauplii	A. salina eggs (viable)	5-10 eggs/ml
d. Chaetoceros + A. salina + Brachionus	Brachionus (live)	3-7 indl's/ml
e. Chaetoceros + Brachionus		
f. Chaetoceros + Bread yeast	Bread yeast	1 g/ton
g. Chaetoceros + A. salina eggs		
h. Spirulina	Spirulina	1 g/ton
i. Egg powder + Chaetoceros	Egg powder (100 mu)	approx. 100 particles/ml
j. Chaetoceros + squid meal	Squid meal (100 mu)	approx. 100 particles/ml
k. Chlorella	Chlorella (live)	100,000-500,000 + cells/ml
l. Chlorella + Brachionus		
m. Chlorella + Brachionus + A. salina nauplii		
n. no food given		

Table 1b . List of the different feeding formulae used for rearing *S. serrata* in increasing magnitude of larval survival response. A student Newman-Keuls test was applied. Refer to Table 1a for feeding compositions. No significance was found between i and j; n and f; f and a; a, h and k; and c, m and d. v = 28 d.f. SY = 0.076974 at $p \angle 0.05$.

Feeding formulae	Mean survival
i	1.17
j	1.43
n	1.77
f	1.92
a	2.17
h	2.33
k	2.43
e	5.05
g	5.42
l	5.78
b	6.97
c	7.97
m	8.02
d	8.12

Table 2. Body size increments of *Scylla serrata* after first molting under laboratory conditions (January o October, 1977).

	Initial Measurements			Measurements after Molting			Increments			Days duration from
Sex	CL(mm)	CB(mm)	BW(g)	CL	CB	BW	CL	CB	BW	stocking to molting
M	48	76	85	60	87	89	11	11	4	12
F	40	62	47	43	65	45	3	3	2	6
F	48	75	76	60	66	91	12	11	21	7
M	41	66	56	not taken (cannibalized)			-	-	-	5
F	40	65	56	"	"	"	-	-	-	5
F	49	85	100	"	"	"	-	-	-	7
M	50	78	88.3	61	86	104	11	8	15.7	7
F	41	60	43	50	70	60	9	10	13	8
F	52	77	70	72	91	115.1	20	14	45.1	10
F	51	72	54	61	84	97	10	12	43	13
M	not taken	62	40	-	71	57	-	9	17	6
M	64	83	100	74	91	102	10	8	2	1
F	40	63	48	51	72	70	11	9	22	2
M	not taken	75	101.5	-	87	123	-	12	21.5	8
F	" "	77	73.5	-	88	115	-	11	41.5	4
M	" "	62	45	-	73	76	-	11	31	7
F	66	86	112.3	70	97	151.0	4	11	38.7	5
M	not taken	72	40	-	79	53	-	7	13	6
F	65	86	88	84	100	120	19	14	32	6
F	not taken	70	60.5	-	81	73.9	-	11	13.4	4
M	55	78	85	62	85	92	7	7	7	8
M	53	77	50	not taken (cannibalized)			-	-	-	21
F	60	87	36	69	100	124	9	11	24	3
M	45	63	49.5	49	69	57	4	5	7.5	3
F	not taken	68	55.5	-	71	53.3	-	3	-2.2	15
M	46	65	52	53	75	57	7	10	5	9
F	55	80	71	66	100	129	11	20	58	8
F	55	80	85	65	95	129	10	15	44	12

Table 2 (cont'd)

Sex	Initial Measurements CL(mm)	CB(mm)	BW(g)	Measurements after Molting CL	CB	BW	Increments CL	CB	BW	Days duration from stocking to molting
F	55	80	88	63	90	103	8	10	15	17
F	63	92	148	70	102	165	7	10	18	4
F	46	69	59	55	84	80	9	15	21	6
F	50	73	75	59	84	61	9	11	-14	9
F	55	80	94	69	102	132	14	22	38	13
F	53	74	67	63	90	94	10	16	27	10
F	71	95	146.1	77	115	204	6	20	57.9	14
F	53	80	74.5	unfinished molt, died			-	-	-	
F	57	86	93	67	105	119	10	19	26	9
M	50	72	61.5	not taken (cannibalized)			-	-	-	21
F	50	82	66	62	90	90	12	8	24	35
F	58	81	108	60	87	80	2	6	-28	28
M	50	72	60	57	83	88	7	11	28	40
M	56	82	80.2	not taken (cannibalized)			-	-	-	22
F	65	94	141.5	72	103	164.8	7	9	23.3	8
M	50	72	86	56	80	96	6	8	10	27
F	43	60	46	44	65	511	1	5	11	22
F	46	66	39	49	73	77.5	3	7	38.5	34
F	46	66	39	49	73	77.5	3	7	38.5	32
F	80	114	185	81	120	244.5	1	6	59.5	41
F	54	74	65	64	94	109	10	20	44	33
M	41	59	33	50	69	46	9	10	13	30
F	42	62	47	56	82	81	14	20	34	30
F	50	74	63	62	90	93	12	16	30	41
F	41	68	53	55	88	89	14	20	36	33
F	45	67	56	55	83	83.1	10	16	27	43
M	40	62	32	49	73	50.2	9	11	18.2	30
F	45	65	35	51	75	55.7	6	10	20.7	25
M	43	63	47.6	51	72	59.5	8	9	11.9	17
Total-57 19 M 38 F	2562	4235	4050.5	2596	4275	4778.1	427	565	1236.1	872
Ranges:	40-80	60-114	32.148	43-84	65-115	45-244.5	1-20	3-22	[illegible]	

Table 3. Measurements of a newly-molted crab right after molting and until 72 hours later.

	Stocking Measurements	After Molting	15 min. later	72 hrs. later
Carapace length (mm)	75	82	87	87
Body weight	101.5	111	115	123

Note: Feeding activity resumed 28-36 hours later.

Table 4. Record of Mating of S. *serrata* in Captivity from January to August 1977.

Pairs	CB(mm)	CL(mm)	CW(g)	Mating Date	Mating Duration
F	100	--	139	1-30-77	13 hr 50 min
M	--	--	--		
F	82	--	103	3-11-77	22 hr
M	94	--	153		
F	100	--	120	3-9-77	30 hr
M	94	--	155		
F	56	--	56	3-19-77	30 hr
M	94	--	155		
F	100	65	129	5-2-77	24 hr
M	88	56	112.8		
F	95	65	129	5-4-77	24 hr
M	--	--	--		
F	105	76	103	5-5-78	10 hr
M	--	--	--		
F	84	55	80	5-10-77	4 hr
M	--	--	--		
F	102	68	132	5-11-77	24 hr
M	90	62	114		
F	107	75	192	5-18-77	24 hr
M	97	[illegible]	[illegible]		
F	126	88	296	5-18-77	24 hr
M	98	71	237		
F	90	62	90	5-26-77	13 hr
M	--	--	--		
F	96	[illegible]	122.5	6-9-77	24 hr
M	--	--	--		
F	90	60	95	7-27-77	48 hr
M	[illegible]	47	[illegible]		
F	86	[illegible]	94	7-28-77	24 hr
M	--	--	--		
F	[illegible]	56	[illegible]	8-6-77	24 hr
M	--	--	--		
F	[illegible]	56	81	8-6-77	24 hr
M	69	50	[illegible]		
F	62	90	93	8-7-77	24 hr
M	--	--	--		
F	90	[illegible]	93	8-7-77	24 hr
M	--	--	--		

Table 4. (continuation)

Pairs	CB(mm)	CL(mm)	CW(g)	Mating Date	Mating Duration
F	88	55	89	8-9-77	24 hr
M	--	--	--		
F	88	55	89	8-9-77	30 hr
M	69	46	66		
F	83	55	83.5	8-9-77	30 hr
M	69	45	60.5		
F	62	56	85	8-11-77	30 hr
M	--	--	--		
F	36	55	100	8-11-77	30 hr
M	--	--	--		

N = 25 pairs

	CB(mm)	CL(mm)	CW(g)	Mating Duration
Range:	F-62-126	55-90	80-296	4-48
	M-68-98	45-71	46-237	
Average:	F-92.0	64.4	115.5	23
	M-82.11	53.8	125.9	

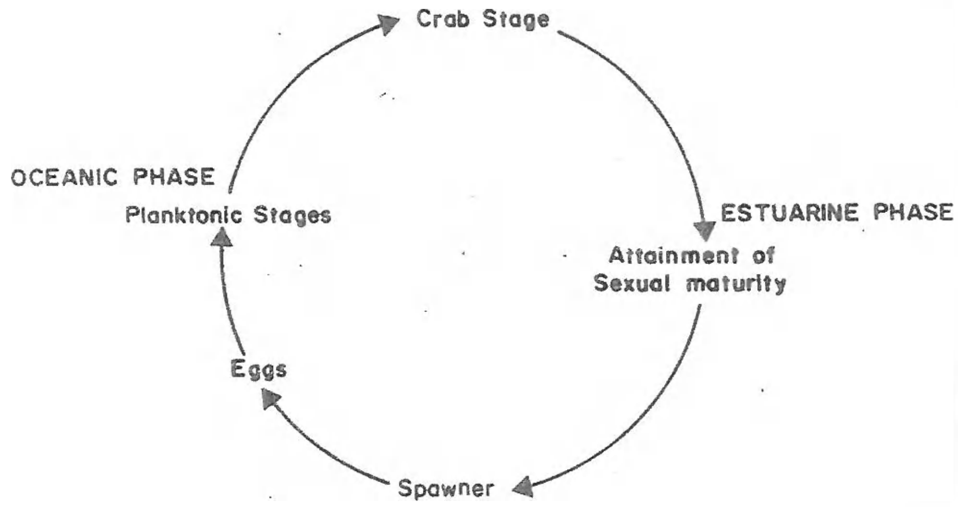


Fig. 1. LIFE CYCLE OF <u>Scylla</u> <u>serrata</u>.
(A. Laviña, 1976)

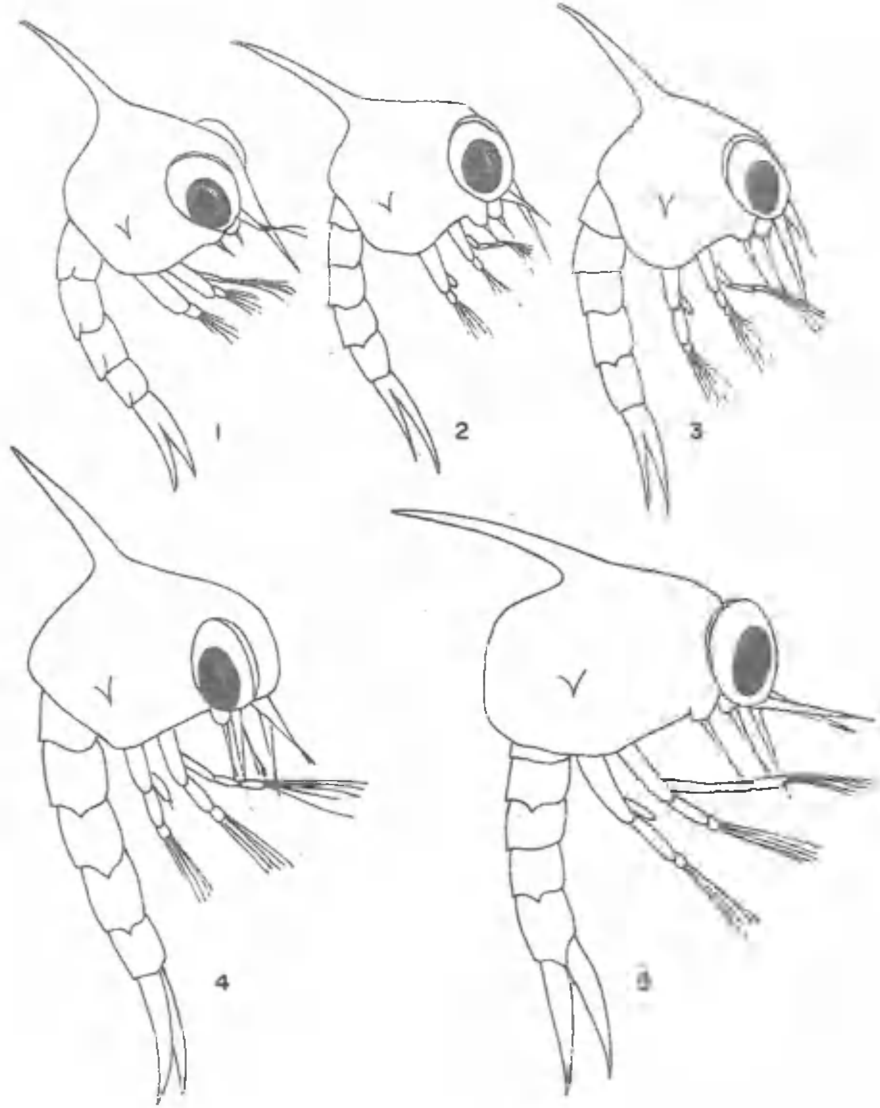


Fig. 2. a. LARVAL STAGES OF <u>S.</u> <u>serrata</u>.
Zoea 1 to Zoea 5.

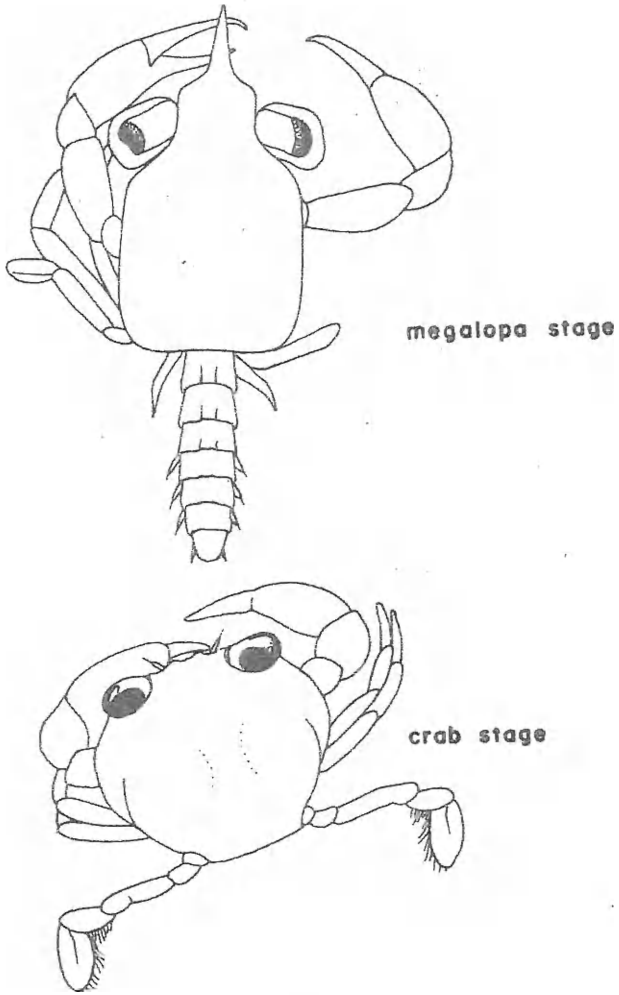


Fig. 2 b. LARVAL STAGES OF *S. serrata*.

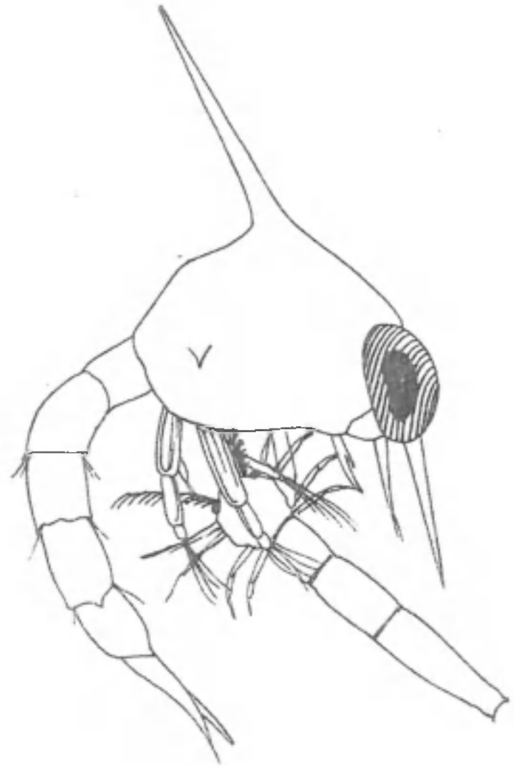
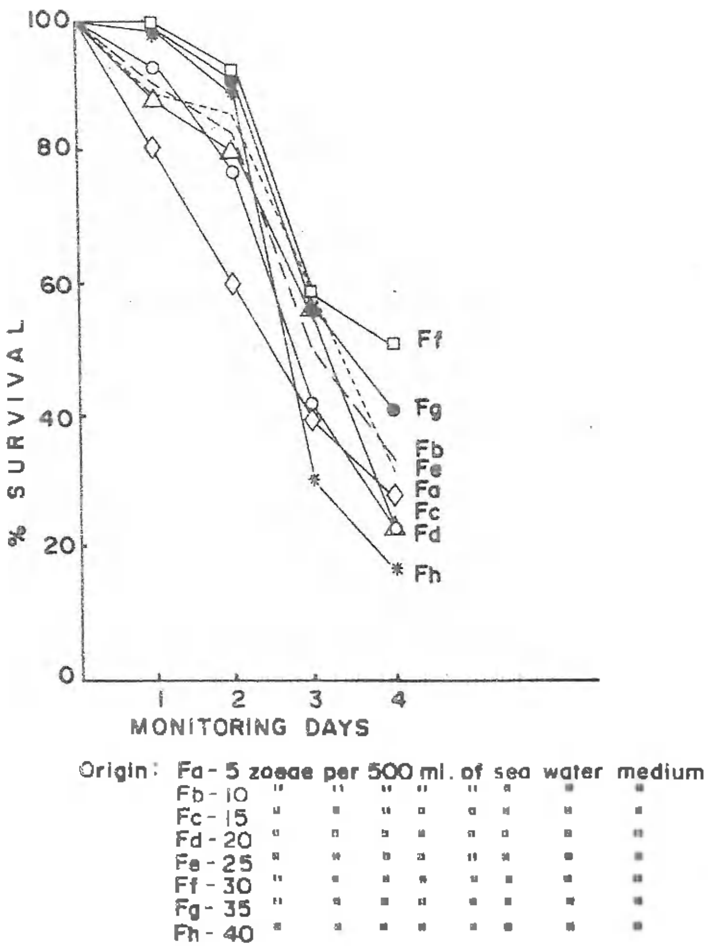


Fig. 3. *S. serrata* ZOEA CATCHING *Artemia* NAUPLIUS.

Fig. 4. PERCENTAGE SURVIVAL OF *S. serrata* LARVAE (zoea I) AT DIFFERENT STOCKING DENSITIES.



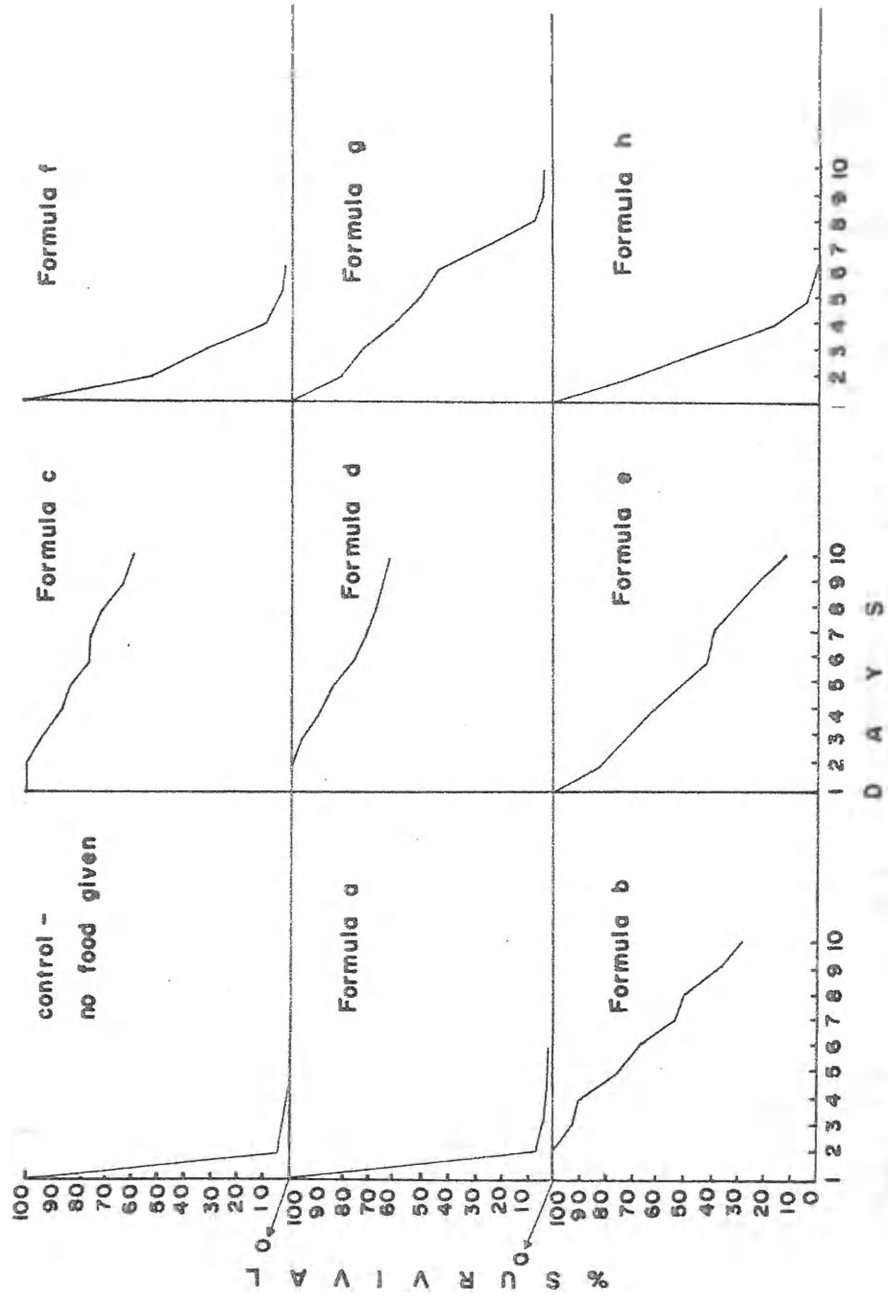


Fig. 5. PERCENT SURVIVAL OF *S. serrata* LARVAE DURING REARING PERIOD OF 10 DAYS IN THE DIFFERENT FEEDING FORMULAS. REFER TABLE I FOR FORMULA COMPOSITION

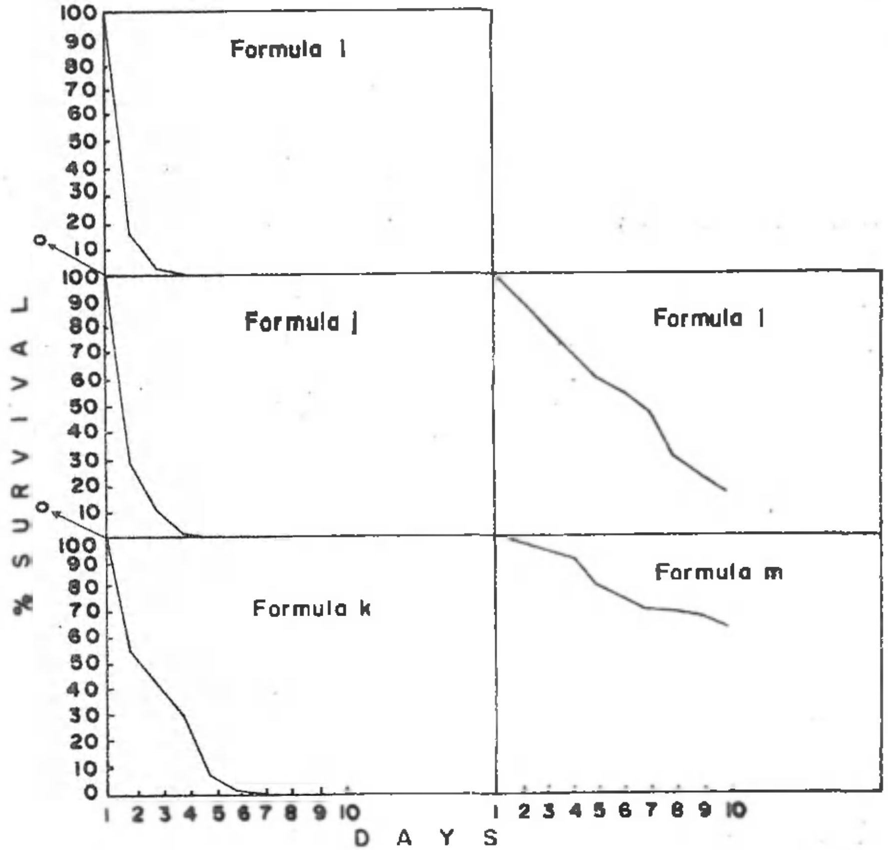


Fig. 5. (continued)

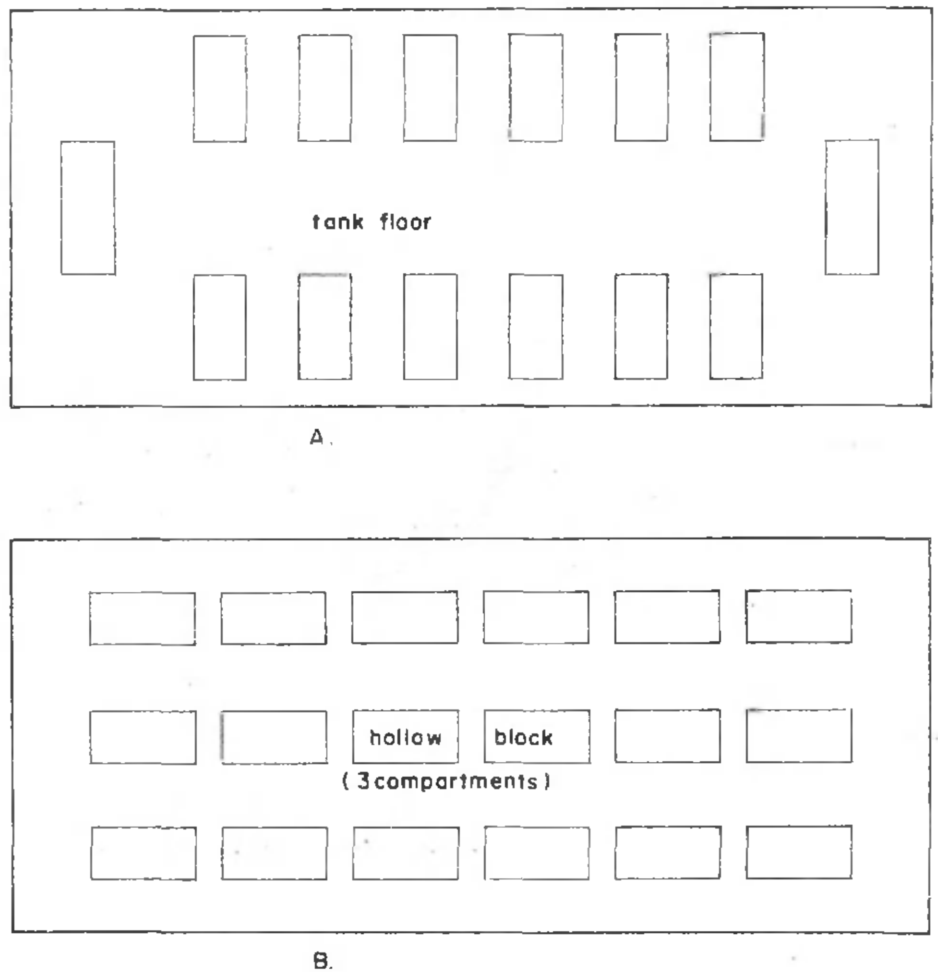


Fig. 6. HOLLOW BLOCKS (3 compartmented units) AS REFUGE SYSTEM FOR CRABS RAISED IN CAPTIVITY.

A & B ABOVE ARE SAMPLE ARRANGEMENTS.

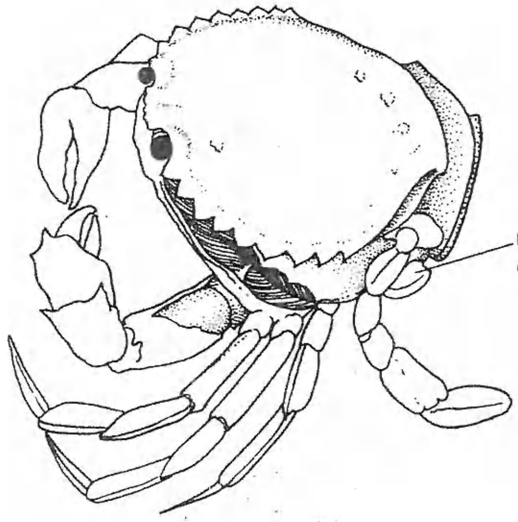


Fig. 7. A MOLTING <u>Scylla</u> <u>serrata</u>.

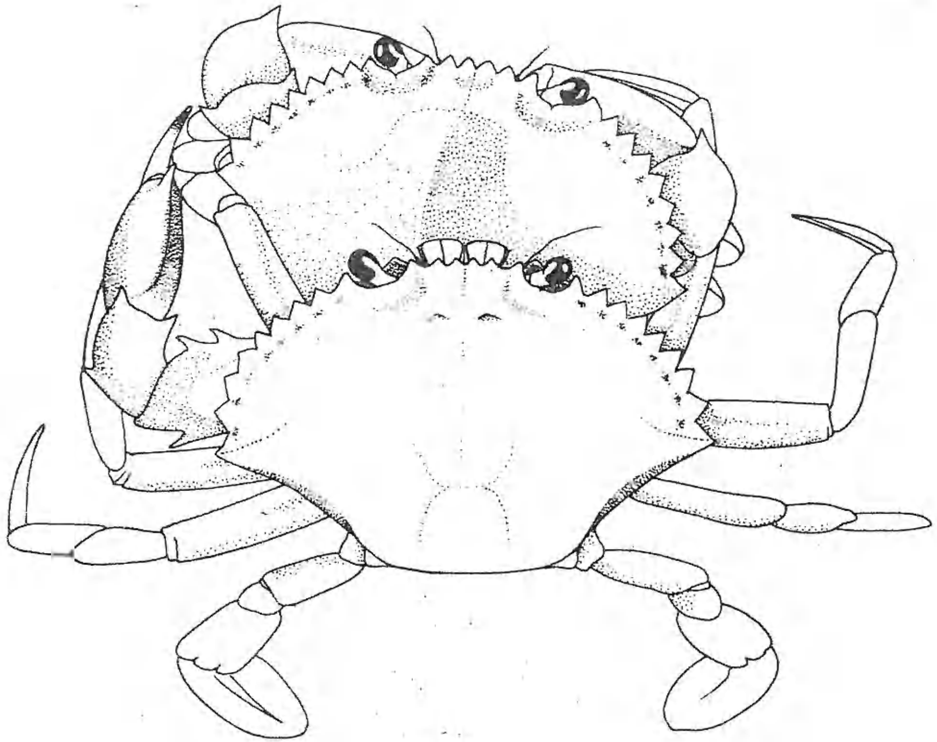


Fig. 8. <u>Scylla</u> <u>serrata</u> COUPLE EXHIBITING PRE-COPULATORY BEHAVIOR. (PCB)

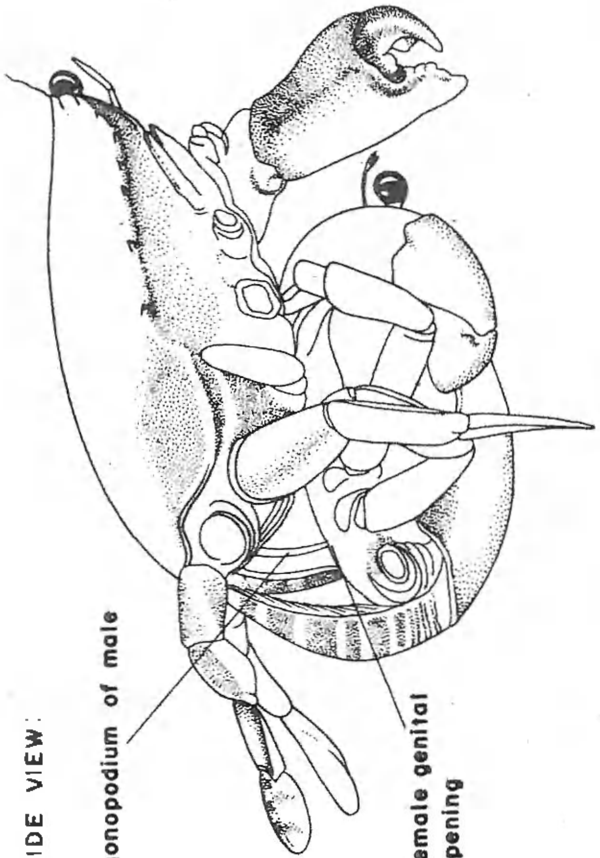
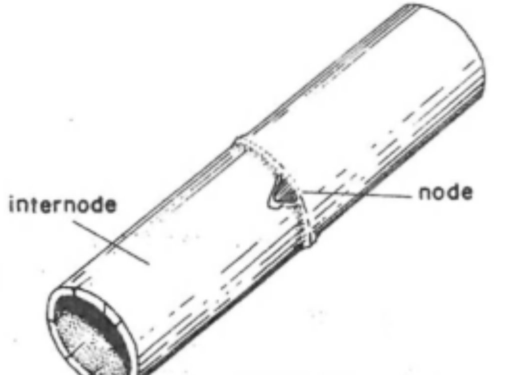
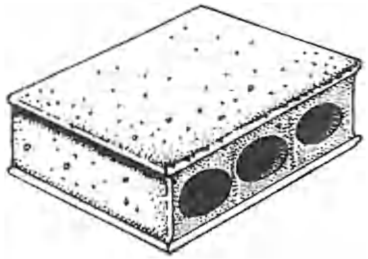


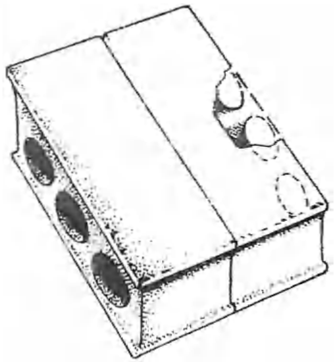
Fig. 9. MATING COUPLE OF Scylla serrata. (F) de Haan.



a. Bamboo crab refuge



b. Hollow block with 3 compartments



c. 6-compartmented hollow block

Fig. 10. REFUGE SYSTEM TYPES FOR CRABS RAISED IN PONDS.

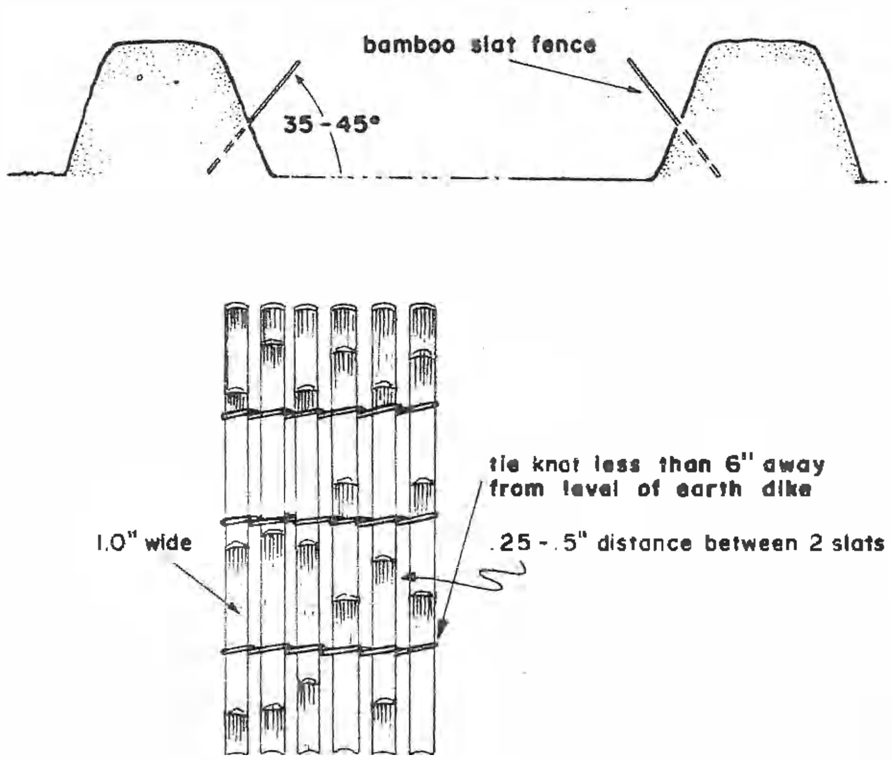


Fig.11. SIDE VIEW OF CRAB POND WITH EARTHEN DIKES.
SHOWING DETAILS OF BAMBOO SLATS.

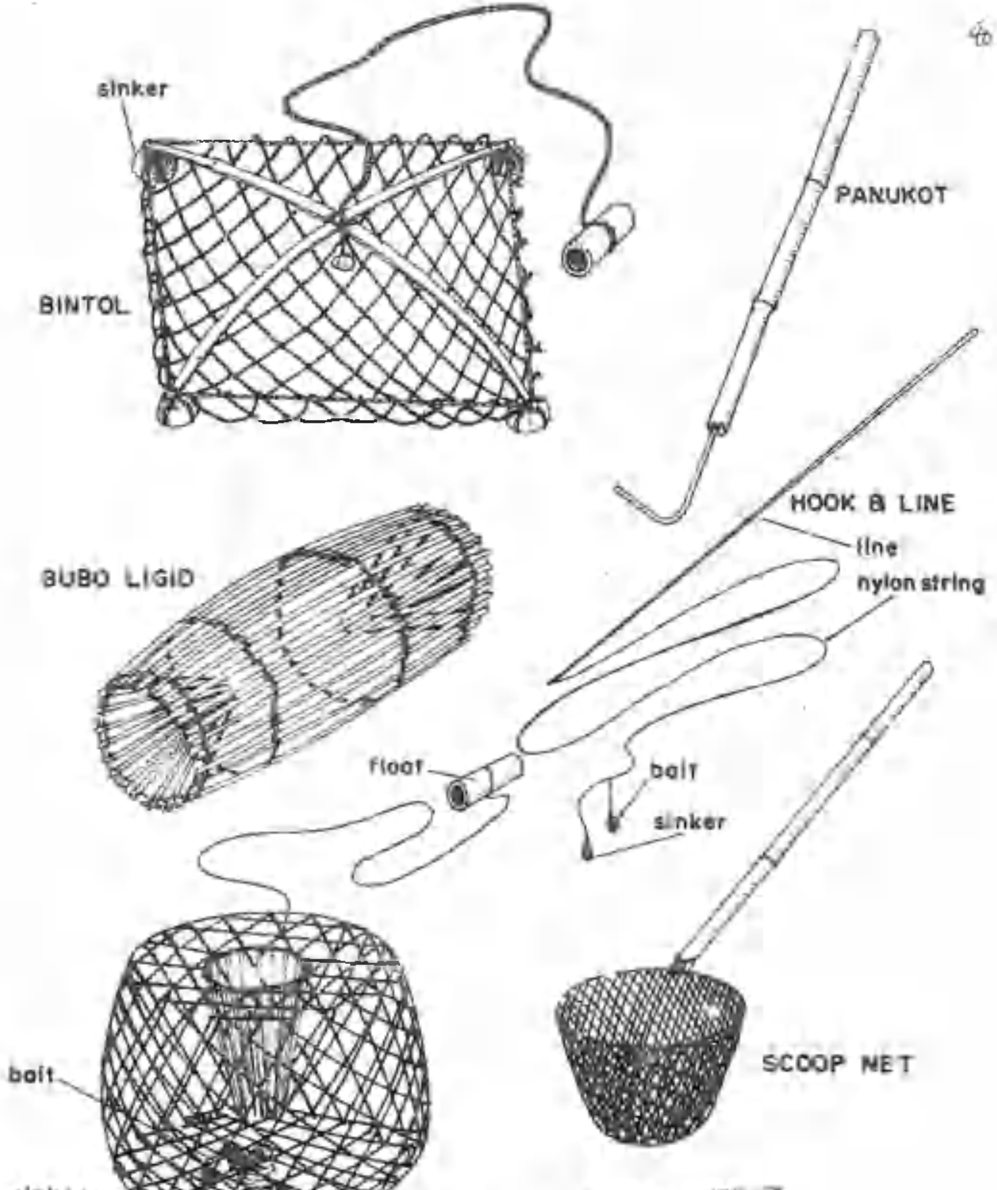


Fig. 12. PHILIPPINE CRAB TRAPS.