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Life-cycle of the Pea Crab, *Pinnotheres vicajii* Chhapgar, Infesting the Clam, *Paphia malabarica*

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Various crab stages commencing with the invasive stage to adult stages of male and female in the life cycle of *Pinnotheres vicajii* infesting the edible clam, *Paphia malabarica*, occurring in the Mandovi estuary of Goa have been described. Except the adult male and female the rest of the stages have been described here for the first time in this species. Zoeae larvae liberated from the eggs carried by ovigerous females are characterized by the presence of 3 spines on the carapace. Comparison of these larvae with those of other species has been attempted. Planktonic zoeae larvae in the estuary occur almost throughout the year with 2 peak periods in May-June and December-January, coinciding with high salinity conditions of waters. Egg counts of 12 ovigerous females of different sizes show a minimum of 611 and a maximum of 3800 with an average of 1853 eggs. An attempt has been made to study the host-symbiont relationship. No signficant damage has been noticed on the soft parts of the host and there is no marked difference in the meat weight — whole weight relationships of the infested and non-infested clams. However, a slight decrease has been noticed in the averages of meat weights of infested clams in the bigger whole weight groups.

WHILE studying the breeding periodicities of some of the economic bivalve species, frequent occurrence of a small pinnotherid crab in the mantle cavity of the clam, *Paphia malabarica* (Chemnitz) has been noted. It has been ascribed to the little known species of *Pinnotheres vicajii* Chhapgar[1,2] with which it agreed in most taxonomic characters with minor differences. All heterospecific associations, other than predation are now recognized to be symbiotic associations. The ecological term, 'symbiosis' meaning 'living together' is categorized into parasitism, mutualism, commensalism and phoresis[3]. Accordingly *P. vicajii* is a symbiont within *P. malabarica*. A symbiont-host relationship is difficult to be categorized without a knowledge of the biology of both the species involved and a thorough understanding of the nature and extent of dependence, mutual or one sided, complete or partial and whether such an association is accompanied by deriving or conferring benefit or causing or receiving harm by one or the other of the two partners. Whether the type of association of *Pinnotheres* spp with bivalve molluscs could be considered in general as one of commensalism or parasitism is not fully answered. While Rathbun[4] has considered a large number of American species of *Pinnotheres* as commensals, Orton[5] and Christensen and McDermott[6] have regarded *P. pisum* and *P. ostreum* to be parasitic in the oysters causing at times immense injury to the host tissues. Silas and Alagarswami[7] have also noticed a species of *Pinnotheres* parasitic in the clam *Meretrix casta*. The main damage noted in all cases is the injury to the labial palps and gill lamellae. For a symbiotic association to be recognized as parasitism, there should be metabolic dependence of the symbiont on the host[3] as in mutualism. In case of commensalism and phoresis such metabolic dependence of the symbiont on the host is wanting. It has been argued that if *Pinnotheres* ever habitually feeds on the labial palps or the gills of the host, the association could be recognized as parasitism. However, in all observed cases, *Pinnotheres* is known to feed on minute organisms brought into the mantle cavity by ciliary currents and getting entangled in the mucus overlying the gills and the palps of the host[5]. The crab directs this mucus ventral to the body with the help of the walking legs while the chelipeds gather the organisms and pass them into the mouth. It is in short a commensal mode of feeding. It is in this act, the vigorous movements of the crab's appendages bring about a certain amount of injury to the host. By interfering with the normal feeding activity, the symbiont may still bring about a certain amount of physiological imbalance in the host, but direct evidence is lacking.

Pinnotheres spp exhibit strong sexual dimorphism, the males being recognizable from the females not only by their smaller size but also by their secondary sexual characters. The crab phases inhabiting the host's mantle cavity differ from one another at different growth stages. Mating in a few cases is stated to take place in the macroenviornment i.e., the ambient environment of the host and in others possibly within the microenvironment i.e., within the host's mantle cavity. The number of zoea stages is also known to vary with species. Most pinnotherid species from the Indian subcontinent, including *P. vicajii*, are known hitherto only from the adult structure of male and females. In view of the paucity of information on the subject and ready availability of the material, an attempt is made here to study all the crab stages of *P. vicajii* infesting *P. malabarica*, the free living larvae, their abundance in the ambient environment and the host-symbiont relationships as far as possible. *P. malabarica*, being a much used clam as food in this region, a knowledge of the nature and effects of its infestation by the symbiont will not be without scientific interest.

Materials and Methods

In order to study various crab stages of both males and females of *P. vicajii*, fortnightly samples of the host clam, *P. malabarica*, were obtained over 2 yr (from June 1972) from the Mandovi estuary close to the Panaji city of Goa. Samples were brought to the laboratory and a small number of clams were examined in fresh condition to obtain the live crab stages for careful macro- and microscopic examination. The rest of the sample was preserved in 5% formalin for a week. The clams were then measured (in mm length). After taking whole weights they were opened to note the exact positions of the symbiont crab in the mantle cavity and the extent of damage, if any, on the host tissues. Number of symbionts in each host, whether they were males or females and their growth stages i.e., invasive, prehard, hard and soft stages were noted. Meat weights and sex of the host were also noted to find out differences, if any, in the meat weight-shell weight relationship in the infested and the non-infested clams.

While examining fresh clams, berried female crabs with eggs in advanced stages of development were carefully removed and kept in finger-bowls containing sea water, which was changed daily until the zoea larvae were liberated. The structure of these larvae was studied and compared with similar larvae in allied species earlier described. Larvae were reared in small groups in separate finger-bowls over 10 days, but no further development took place under laboratory conditions.

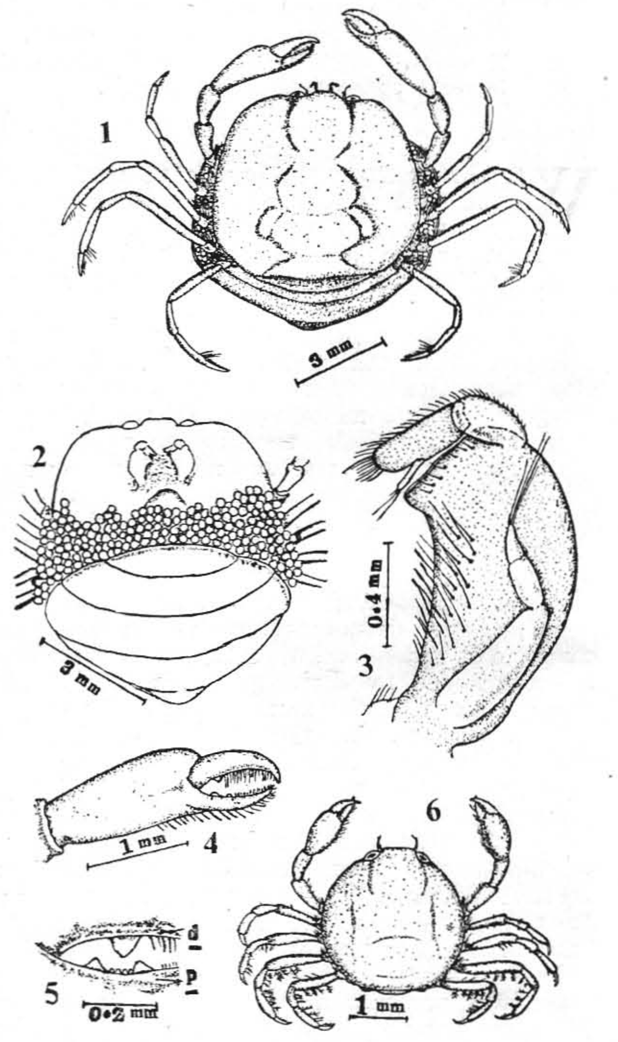
Planktonic larvae conforming in structure to the hatched out larvae were obtained in tow-net collections in the estuary at 3 selected stations. In these collections some megalopae with 3 rudimentary carapace spines have been considered to belong to the present species. Monthly frequencies of both the zoeae and the megalopae from these stations have been worked out to find out their seasonal abundance.

Results

Mature female — Mature ovigerous females were obtained in varying numbers in almost all months of the year in the clams examined. In the total females examined each month, they were on the increase from January (29·41%) to April (72·2%); February and March registered 35·89 and 45·16% respectively. The numbers of the ovigerous females gradually diminished from May (38·4%) to July (nil %). Description of the ovigerous females is as follows:

Yellowish brown; carapace subquadrate with width exceeding length (6·5×5·8 mm); surface soft, smooth, slightly convex; with one anterior median oval elevation and 2 transverse elevations behind, marked off by faint depressions on surface; front slightly elevated; eyes small reddish brown and partially covered by front; posterior margin of carapace straight; broad and about 2½ times wider than front; orbits subcircular; antennules shorter than diameter of orbits; antennae large; merus-ischium of the pair of external maxillipeds evenly curved on outer border and about 4 times larger than carpus, set with long hairs on flat side and also on anterior and inner borders; submarginal setae on outer border extremely small; carpus small, round and hairy on outer border; propodus long, broad, distally rounded, extending a little beyond the inner anterior border of merus-ischium and setose on its outer border; dactylus long finger-like articulating at about inner middle portion of propodus and hairy at tip (Figs. 1-3).

Merus-ischium and carpus of cheliped slender; palm flat elongated, length exceeding 3 times the width; propodial finger and dactylus toothed at opposing bases and overlapping distally at recurved tips; dactylus with single tooth fitting in interspace between 2 smaller teeth on opposing face of propodial finger; interspace on dactylus also with 2 or 3 minute denticulations (Figs. 4 and 5); walking legs in 4 pairs, 3rd pair the longest; first pair shorter than the 4th pair; left side appendages often slightly longer than the right side ones; dactyli of all walking legs pointed at tips and gradually increasing in length from the first to the last pairs;



Figs. 1-6 — *Pinnotheres vicajii* [Fig. 1: Dorsal view of ovigerous female. Fig. 2: Ventral view of ovigerous female with eggs. Fig. 3: External maxilliped of the same. Fig. 4: Palm of cheliped showing the structure of dactylus and propodial finger. Fig. 5: Magnified view of the inner portion of dactylus (*d*) and propodus *p*) showing the arrangement of teeth. Fig. 6: Dorsal view of the hard stage female] coxae, inner basal portions of merus-ischia of all walking legs, inner distal portions of propodi of 3rd and 4th and occasionally of the 2nd pairs of walking legs hairy (Fig. 1).

Abdomen broad, wider than the base of carapace, flexed ventrally, extending from behind forwards covering coxapodites of all walking legs; entire margin finely setose; inner surface of abdomen and outer surface of throrax hollowed forming a pouch holding numerous eggs borne in clusters by 4 pairs of abdominal appendages (Fig. 2).

Carapace dimensions in specimens of ovigerous females ranged from 4·5-7·8 mm in length and 5·0-8·2 mm in width.

Hard stage female — Hard stage females conforming to the following description have been met with sporadically.

Carapace circular, well calcified, length equal or almost equal to width (2·7×2·7 mm); front between eyes elevated, straight and $\frac{1}{4}$ of the width of carapace; eyes well developed and comparatively smaller in size and chelipeds and walking legs relatively slender and longer than in same stage male; inner border of palm of cheliped hairy from base to tip of propodial finger; teeth and setae on opposing fingers as in other stages; coxae of all four pairs of walking legs setose; 1st pair of walking legs with very few minute setae on all joints; 2nd pair of walking legs more hairy than the 1st especially in joints of left side leg; 3rd and 4th pairs with densely branched setae on merusis-chia, carpi and propodi; dactyli of all walking legs minutely setose (Fig. 6).

Abdomen very narrow, about a $\frac{1}{3}$ of width of carapace, extending forwards ventrally, fitting into sternal depressions; margin of abdomen hairy; distinguishable from male by absence of copulatory appendages and presence of minute biramous appendages in 4 pairs.

Posthard stages of female — Hard stage female is stated to be in stage I, which undergoes successive moltings resulting in soft stages II to V. In these the carapace grows in dimensions, gradually ceases to be roundish and assumes a subquadrate form; the abdomen which is narrow to begin with, widens and takes the form of a cup; and the abdominal appendages from their rudimentary condition are elaborated in structure becoming biramous and setose. At stage V, the gonad, which is deep orange red is clearly seen through the translucent carapace.

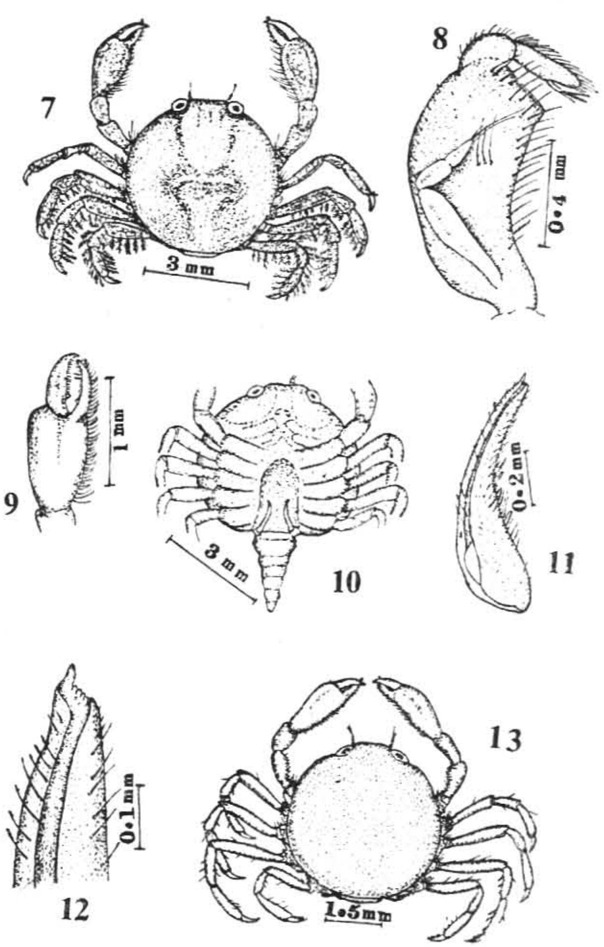
The posthard stages of female met with in the clam hosts were all above 3 mm of carapace length. A good number of them in successive stages were met with in clams examined in several months, but were abundant in July 1974.

Hard stage male — These have been met with round the year. Colour grayish brown against a background of pale yellow; carapace hard, convex, smooth, well calcified without trace of anterior angles; eyes orbicular; front between eyes straight and slightly elevated, measuring about $\frac{1}{4}$ of carapace width; posterior border broadly rounded, but straight at articulation of abdomen; anterior, middle and posterior elevations on carapace not prominent and marked off by faint depressions on surface bordering them. Merus-ischium of external maxilliped as in female, but relatively smaller; carpus small and rounded and hairy on outer border; propodus long; narrow extending considerably beyond the level of merus-ischium and hairy on outer border (Figs. 7 and 8).

Merus-ischium and carpus of cheliped moderately stout; palm prominently bulged at base of claws; dactylus claw-like, prominently arched and with a single prominent tooth at base; propodial finger also claw-like, distally overlapped by recurved tip of dactylus (Fig. 9); tooth of dactylus fitting in interspace between two small teeth on inner surface of propodial finger; interspace also bearing 2 or 3 other minute inconspicuous teeth-like projections; opposing inner surfaces of the claws setose; palm and propodial finger hairy.

Walking legs in 4 pairs, 3rd pair being the longest, 1st pair about the same length as the last pair or slightly longer, but always more slender than others; 2nd pair longer than the 1st and the 4th; dactyli of walking legs recurved and sharp pointed; branched setose hairs present on merus-ischium, carpus and propodus, both on upper and lower surfaces in the 4th walking leg and on the lower surfaces only on 2nd and 3rd walking legs; dactyli of all walking legs setose; coxae of all appendages also setose (Fig. 7).

Abdomen narrow (Fig. 10), measuring about a 4th of width of carapace, 7 segmented, flexed



Figs. 7-13 — *Pinnotheres vicajii* [Fig. 7: Dorsal view of the hard stage male. Fig. 8: External maxilliped of the same. Fig. 9: Palm of cheliped showing the structure of dactylus and propodial finger. Fig. 10: Ventral view of the same showing the narrow abdomen and the location of copulatory pleopods. Fig. 11: Copulatory pleopod. Fig. 12: Tip of copulatory pleopod enlarged. Fig. 13: Dorsal view of soft male] behind fitting ventrally in sternal depression, copulatory pleopods blade-like wide at base, narrow distally, outer and inner margins hairy, tip minutely lobed, channel running from tip to base (Figs. 11 and 12); 2nd pair of pleopods very small rod-like and without hairs.

Carapace width of hard shelled males in the samples ranged from 3·0-4·3 mm and length from 3·0-4·1 mm.

Soft-shelled male — Generally about the same size as the hard stage male or slightly larger; carapace soft, smooth and orbicular; front elevated and ⅛ width of carapace. Eyes well exposed dorsally; anterolateral angles of carapace slightly rounded; antennules and antennae as in hard male; chelipeds and walking legs slender and longer than in hard male; coxae of chelipeds and of all walking legs setose; all walking legs sparsely setose on upper and lower borders. Hairs on inner distal portions of propodi of 3rd and 4th walking legs often longer; some specimens marked by greater sparsity of hairy outgrowth than others on the walking legs; abdomen narrow, ⅓ the width of carapace, flexed, fitting into sternal groove extending up to base of chelipeds as in hard male (Fig. 13).

Carapace dimensions of specimens examined ranged from 2·3-3·8 mm in length and 2·3-3·8 mm in width. This stage is usually termed the stage II male. In males there are no other stages succeeding this.

Prehard stage — Commonly obtained in most monthly samples of clams.

Carapace round, length about equal to width (2·1×2·2 mm), soft and yellowish; front broad and slightly elevated; eyes prominent and rounded; chelipeds and walking legs slender and elongate; hairy outgrowths on appendages sparsely distributed; 3rd pair of walking legs the longest and the last pair shortest; externally sexes indistinguishable (Fig. 14).

Carapace dimensions of specimens examined ranged from 1·2-2·6 mm in length and 1·3-2·6 mm in width.

Invasive stage — This is the smallest crab stage observed in fair numbers in the host in March-April.

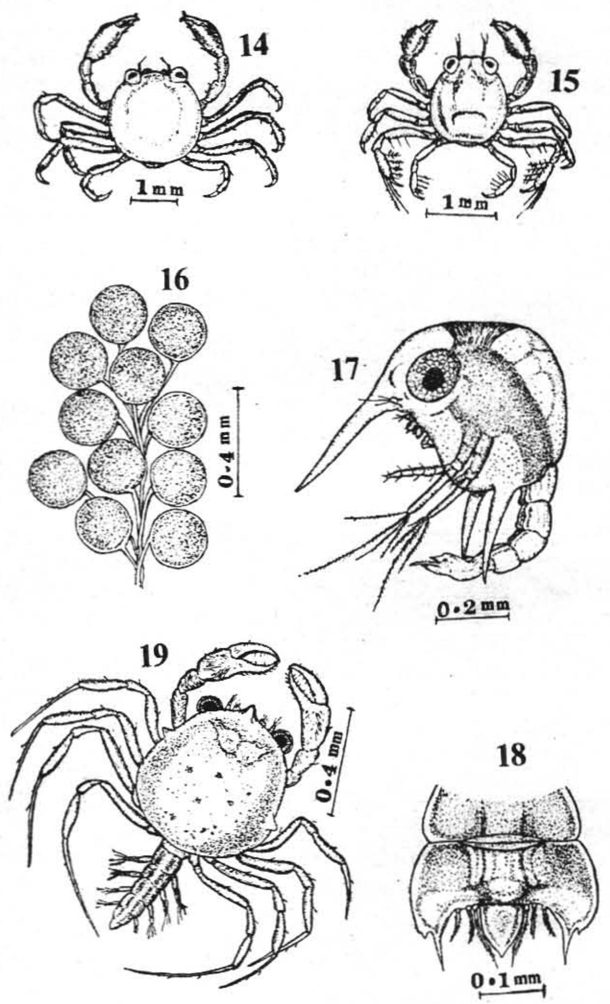
Light grayish brown against pale yellow background colouration; carapace oblong, length greater than width (1·3×1·2 mm); front elevated; slightly bilobed, prominently angled at sides and ⅓ the width of carapace; posterior region rather truncate at articulation of abdomen; eyes large, reddish brown, very prominent; chelipeds stout; palm hairy and proportionately wider than in other stages; claws slender and much overlapping; walking legs in 4 pairs; 1st pair slender and shorter than the 2nd and last pairs, 3rd pair the longest; 3rd pair of walking legs with moderately long setae on merus-ischium and much branched setose hairs on upper and lower surfaces of propodus, those on upper distal surface being the longest, extending far beyond the tip of dactylus; last pair of walking legs with branched setae on lower surface of propodus: dactyli of all walking legs claw-like and sharp pointed (Fig. 15).

Carapace dimensions of specimens examined ranged from 1·3-1·4 mm in length and 1·1-1·2 mm in width.

Zoea larvae — After completion of the embryonic development, fully formed zoea larvae were liberated from the eggs carried by berried females kept under observation in finger-bowls (Figs. 16 and 17). In structure they were typical of the crab zoea with some special features as described below:

Colour light yellowish brown; carapace 525 µm in length by 415 µm in width; rostral spine about 350 µm long directed forwards, lateral spines 1 pair, directed slightly hindwards; eyes large 150 µm in diam. antennule uniramous, antennae biramous, mandible with palp, maxillae in two pairs; maxillipeds in 2 pairs, well developed and biramous; exopodite of each maxilliped with 4 long plumose setae at distal joints; abdomen well developed, dorsoventrally flattened, narrow at origin from cephalothorax, considerably broad posteriorly, 5 segmented, last segment widest about 300 µm broad; telson trilobed, median lobe ovate, lateral lobes large, free margins produced into sharp spinous processes; three setose spines on either side movably articulated on lateral lobes adjoining median lobe (Fig. 18).

The zoeae could be kept alive for a maximum period of one week, but most of them died even after the 3rd day. An attempt was made to feed them with phytoplankton, but no further changes took place before they died.



Figs. 14-19 — *Pinnotheres vicajii* [Fig. 14: Prehard stage. Fig. 15: Invasive stage setose hairs on the 3rd and 4th walking legs may be noted). Fig. 16: A portion of the egg mass enlarged. Fig. 17: Zoea larva lateral view. Fig. 18: Telson of zoea larva showing the trilobed nature with setose spines. Fig. 19: Megalopa]

Megalopa — In the life-history of *Pinnotheres* species in general the zoea stages are known to be followed by megalopa. The zoeae of the present species of *Pinnotheres* could not be reared up to megalopa, but megalopae were obtained in the plankton collections made in the Mandovi estuary. In the environment several types of megalopae were met with, but those with much reduced rostral and lateral spines on the carapace were considered as belonging to this species and have been figured and described.

Colour pale yellowish brown; carapace 600 µm long and 500 µm wide, roundish, anterior border comparatively narrower than posterior border, spines unpaired rostral and paired laterals much reduced but still discernable; eyes large; cephalic appendages as in zoea but better developed; thoracic appendages well developed as in adult with 3 pairs of maxillipeds, 1 pair of chelipeds and 4 pairs of slender jointed, sparsely setose walking legs with long dactyli, those of the last pair being the longest; abdomen slender, 7 segmented, smaller than carapace, 400 µm in length and 100 µm in width with 4 pairs of jointed setose appendages (Fig. 19).

Frequency of zoeae in plankton — Frequency of occurrence of zoeae larvae in the plankton samples from Mandovi estuary conforming in structure to the larvae reared under laboratory conditions was estimated for 1 yr from June 1972 to May 1973. Three stations were chosen, 1st towards the sea, a 2nd right in the river mouth, and a 3rd a little farther up the river.

The surface zooplankton samples were collected using a modified WP-2 net (Unesco[8]). The plankton net was made of nylon gauze with a mesh width of 0·3 mm. Duration of haul varied 3-5 min and on an average 70 m^3 of water was filtered/haul. An aliquot sample of 100 ml was examined for the number of larvae, each fortnight and averaged for each month at each station.

The larvae (Table 1) were found to occur all the year round except in the month of August. In general their occurrence was greater at the 2nd station and there were 2 peak periods of abundance, i.e. in December-January and May-June periods. It appears thus the species breeds round the year and that the appearance of the larvae in the surface waters of the estuary is in fair to rich numbers from November onwards of 1 yr up to June of the following year.

Occurrence of the megalopae in the plankton, however, did not follow the same pattern as the zoeae. They have been noticed only in the months of September and December in a few numbers. It is likely that the megalopae inhabit the subsurface layers of the water column rather than the upper layers wherefrom alone the plankton was collected for estimation of larval abundance.

During the period of observations, taking all the stations together, the water temperatures varied only within a small range from 26°C (February) to 32·05°C (April) (Table 1). Salinity variations however, were in a wider range from 3·76‰ (July) to 35·84‰ (May). From July to September the salinity was low at all stations and correspondingly the larval abundance was also either very low or altogether nil. During the highest abundance of larvae in December-January, the salinities were on the increase in all the stations as compared with those obtained in previous months. During the month of May also when 2nd peak of larval abundance was noted, the salinity value remained fairly high. There is thus an indication that higher ranges of salinity of waters are favourable for the larvae to thrive. Of the 3 stations, the one right on the inlet has shown greater abundance of larvae.

Fecundity — Egg counts were taken in 12 ovigerous females with carapace ranging in length from 5·0-7·8 mm and width from 5·7-8·4 mm. Eggs with initial stages of development, measuring about 400 µ in diam. were orange yellow and those with advanced embryos were larger in size and grayish brown. The number of eggs varied from 611 in the smallest crab of 5 mm to 3800 in the largest one

TABLE 1 — LARVAL FREQUENCY, TEMPERATURE AND SALINITY AT THREE STATIONS IN MANDOVI ESTUARY, GOA

Month	Station 1			Station 2*			Station 3†			Three stations average zoeae
	Temp. °C	Salinity ‰	No. of larvae	Temp. °C	Salinity ‰	No. of larvae	Temp. °C	Salinity ‰	No. of larvae	
					1972					
June	28·6	18·01	57	28·60	17·72	3	28·80	16·99	3	21
July	26·9	8·37	0	26·90	8·32	3	27·00	3·76	0	1
Aug.	26·4	13·99	0	26·50	10·28	0	27·20	4·36	0	0
Sept.	27·3	23·59	0	28·40	16·54	0	29·40	11·40	5	2
Oct.	29·98	34·30	4	30·40	28·53	6	30·40	24·22	0	3
Nov.	28·90	32·85	14	28·85	29·24	7	28·90	26·84	42	21
Dec.	27·40	34·11	122	27·90	31·11	22	28·00	28·08	173	106
					1973					
Jan.	27·75	34·96	52	28·05	33·63	226	28·20	32·29	165	148
Feb.	26·10	35·59	9	25·85	35·32	11	26·25	35·05	6	9
March	29·45	36·42	14	29·50	35·01	95	29·70	34·13	30	46
April	32·05	35·67	8	32·00	35·52	70	31·80	35·67	6	28
May	31·2	35·64	10	30·00	35·84	294	30·50	35·58	48	117
Total	—	—	290	—	—	737	—	—	478	502
Average	28·50	28·63	24·18	28·58	26·42	61	28·85	24·03	32	42

*Sept. — 1 megalopa. †Dec. — 5 megalopae.

of 7·8 mm in carapace length. Average number of eggs in 12 crabs was 1853. In the sample only 2 crabs had less than 1000 eggs each, 2 with 2000 and above and the rest between 1339 and 1980.

In *Pinnotheres* sp. infesting *Meretrix casta*, Silas and Alagarswami[7] have noted 1700 to 2800 eggs with an average of 2250, ranging in diameter from 0·32 to 0·38 mm in 6 of the individual crabs examined. In the present observations the minimum number of eggs is less and the maximum number greater than in the above findings.

It is not known how many times an individual crab liberates the eggs in its life time, or in 1 yr or even in one breeding season. In the present observations it has been found that one ovigerous female after liberating all the larvae, molted at the end of 40 hr and became berried in the next 24 hr. However, in other berried females this behaviour was not observed under laboratory conditions. From the above finding and from the occurrence of berried females in the host clams and also the planktonic zoea in the enviornment round the year, the rate of fecundity appears to be very high.

Life-cycle — In the present species of *Pinnotheres* from *Paphia malabarica* the earliest free living stage is the zoea which is followed by the megalopa, both stages being planktonic. The berried crabs carrying advanced stages of embryonic development when kept in finger-bowls containing sea water, liberated fully developed zoea larvae described in the foregoing account. The planktonic larvae were identified in the samples from the environment with the help of hatched out larvae observed in the laboratory.

The first crab stage met with in the host is the invasive stage which is capable of swimming movements with the help of powerful setose outgrowths on the 3rd and 4th pairs of walking legs. The following stage is the prehard stage, which is sparsely setose. The sexes are externally indistinguishable in both these stages. In the next stage, the hard stage, the males are with a prominent pair of copulatory appendages and females with rather small biramous appendages in 4 pairs on the flexed abdomen. The hard stage individuals regarded as stage I of both sexes are densely hairy on their appendages, more so in males than in females. The walking legs are relatively more slender in females than in males. It appears from the structure of the setose appendages that the hard stage ones are capable of leaving their hosts in search of their mates. In comparison with some of the American species in which the life histories have been fully worked out, it is possible that in the present species also pairing takes place in the waters outside the host. Thereafter, mortality of males occurs in large numbers whilst the females reenter the host's mantle cavity, often accompanied by one or two males.

The hard stage ones undergo molting, with increase in growth and resulting in soft stage ones of the resepctive sexes. The males do not grow beyond stage II and they have been found not to exceed about 4 mm whereas the females grow much larger up to 8 mm in carapace width as a result of greater number of molts passing through stages II to V. Molting takes place even after the liberation of the first brood of larvae, as has been actually observed on one occasion in the laboratory.

Infestation by symbiont and its effect on host — It is understandable that *Pinnotheres* is benefited by obtaining food and shelter in the mantle cavity of the host, but it is often difficult to assess the harmful effects produced on the host. In the present observations in more than 99% out of over a thousand clams examined, no visible damage either to the labial palps, gills or the mantle has been noticed. In a negligible number i.e., 4 among infested clams and 7 among non-infested clams the gill surface has shown small patches of erosion, but it is difficult to attribute these injuries to the infestation by *P. vicajii*.

To ascertain exact location of symbionts in the mantle cavity of the host and also relative proportions of various crab stages infesting the clams, a sample of 229 clams was examined during March to May 1974 when all the stages simultaneously occurred. It was found that 91 clams (39·7%) were infested, 2 with 2 symbionts each, 1 with 3 symbionts and 88 with 1 symbiont each. Of the total of 95 symbionts, 20 were adult ovigerous females, 16 soft nonovigerous females, 4 hard shelled females, 20 hard shelled males, 2 soft shelled stage II males, 25 prehard stage crabs and 8 invasive stage crabs. There were thus fair proportions of ovigerous females, hard stage males and prehard stage ones in the sample, but it may be noted that these proportions are expected to vary from month to month and to some extent from sample to sample even in the same month. Of the crabs 62·2% was located on the left side and 35·71% on the right side of the mantle cavity and 1·78% in the inhalent siphonal region of the host. It has been found that the presence of crabs on the left side of the mantle cavity of the host is more frequent. Only the invasive stages have been found sometimes in the inhalent siphon.

To find out the differences if any in the meat weights of the infested and non-infested clams, more than 130 clams under each category were examined at random. In Fig. 20 the meat weights of individual clams under the 2 categories are plotted against their whole weights. Also the clams have been arranged in whole weight groups at intervals of 2·5 g and the averages of meat weights have been

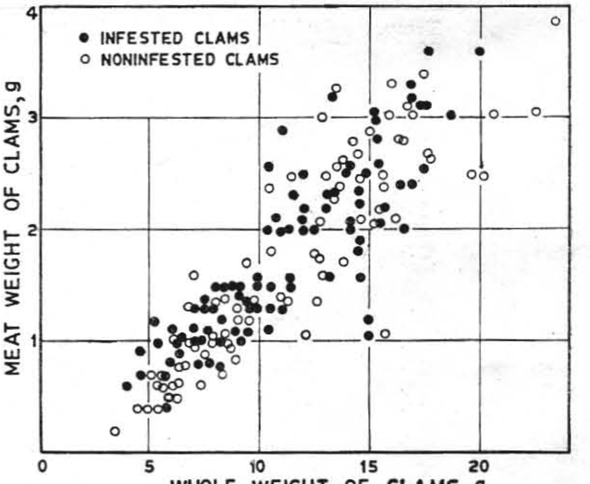


Fig. 20 — Whole weight — meat weight relationship of infested and non-infested clams of *Paphia malabarica* by *P. vicajii*

shown against the respective averages of shell weights, seperately under each category (Table 2). Fig. 20 shows close overlapping of values plotted for infested and non-infested clams with only slight fluctuations met with in both categories. It may be seen from the table that in the whole weight groups up to 12·5 g the meat weights have been about the same or even a little higher but not lower than those of the noninfested clams. In the whole weight groups of 15 g and over the average meat weights of non-infested clams, though negligible, were higher.

In some oysters it has been found that infestation by *Pinnotheres* brings about in the host populations a preponderance of male sex due to interference with the host's normal feeding activity[9]. An attempt is made here to verify dominance, if any, of male sex in *P. malabarica* infested by *P. vicajii*. In this clam, males, females and those of indeterminate sex have been found to occur round the year. From the samples collected over 2 yr about 1000 clams at random were examined to ascertain the relative proportions of the 3 aforesaid sexual phases in the infested and the non-infested clams, which were 618 and 447 respectively, the former forming 58·02% in the total (Table 3). Among the infested clams 50% was male, 26·18% females and 24·11% of indeterminate sex, and among non-infested clams 57·94% was males, 10·73% females and 31·31% of indeterminate sex. It may be seen that the infection observed is of a high order and that in both the infested and non-infested clams the proportion of males is higher than that of females. However, surprisingly the infested clams have shown relatively lower percentage of males (50%) than the non-infested ones (57·94%).

TABLE 2 — SHELL-WEIGHT MEAT-WEIGHT RELATIONSHIP IN INFESTED AND NON-INFESTED CLAMS

Weight groups (whole wt) g	Infested clams		Non-infested clams	
	Av. shell wt	Av. meat wt	Av. shell wt	Av. meat wt
2·5	1·95	0·55	1·70	0·55
5·0	3·74	0·67	3·62	0·66
7·5	5·55	1·08	5·67	0·99
10·0	5·75	1·273	6·57	1·15
12·5	9·22	1·97	9·44	1·89
15·0	11·50	2·22	11·34	2·31
17·5	13·69	2·32	13·72	2·54
20·0	16·28	2·20	16·14	2·86
22·5	17·60	2·75	17·76	3·20
25·0	—	—	20·18	2·85

Discussion

The first description of *Pinnotheres vicajii* by Chhapgar[2] was based on the examination of 4 female and 2 male specimens obtained in *Paphia malabarica* off Bombay coast. In all details of the structure of the carapace and the nature of appendages in the adults, the specimens reported from Goa very closely agree with the first description of the species. Chief among the diagnostic characters are the outline of the carapace, circular in male and subquadrate in the female without any large pigment spots but only scattered grayish granules on its surface; merus-ischium of the external maxilliped being broadly arched, convex on the outer margin and concave on the inner margin with only slight differences in the shape and relative positions of carpus, propodus and dactylus in the two sexes; and in the claws of chelipeds the presence of one large tooth on the movable finger and two large teeth on the immovable finger with reduced ones in the interspace. In the original description it was stated that the surface of the carapace presented no elevations and the abdominal fringe in the male was without hairs, but these characters have been found in a large number of specimens examined and presented in this account. *P. vicajii* is distinct from Rathbun's[10] *P. quadratus* in that the carapace of male in the latter species is subquadrate and its surface covered with large, irregularly shaped pigment spots. *Pinnotheres* sp. infesting *Meretrix casta* described in detail by Silas and Alagarswami[7] is also distinguishable from the present species because of the smooth carapace without any median elevations and also absence of teeth in the claws of the chelipeds in the former.

TABLE 3 — SEXUAL PHASES OF INFESTED AND NON-INFESTED CLAMS

Month	Infested clams			Non-infested clams		
	Males	Females	Indeterminate	Males	Females	Indeterminate
			1972			
Aug.	31	61	1	9	13	—
Sept.	26	15	—	25	25	2
			1973			
Jan.	89	77	38	22	1	20
Feb.	23	1	16	21	1	7
March	7	—	19	1	0	13
April.	25	2	29	34	4	43
May	5	—	1	18	—	4
June	17	—	5	55	—	9
July	21	2	12	8	1	4
			1974			
March	10	1	11	23	2	31
April	41	—	12	34	—	5
May	14	1	5	9	1	2
Total	309 (50%)	160 (25·89%)	149 (24·11%)	259 (57·94%)	48 (10·73%)	140 (31·31%)
Total		618 (58·02%)			447 (41·98%)	

Regarding host specificity of *P. vicajii* not much can be said in the light of present knowledge since in the earlier report and in the present account, it has been found only in *P. malabarica*, but the possibility of its infesting other species of bivalves or any other hosts cannot be ruled out. Chopra[11] has reported *P. deccanensis*, *P. setnai*, and *P. villossima* from holothurian species of the Indian waters. *P. ostreum* which normally occurs in the mantle cavity of the American oyster, *Crassostrea virginica* is often found in association with other bivalves like *Mytilus edulis* and *Aequipecten* and also in other invertebrates as the *Chaetopterus* tubes[3,12]. The European pea crab *P. pisum* which is common in *Mytilus edulis* often occurs in other hosts like the cockles and oysters. Another New World species *P. maculatus* occurs in a variety of bivalves, viz. mussels, clams, scallops, *Pinna* and also in other hosts as the ascidians and annelidan tubes[3,13]. Some of the Japanese pinnotherids as *P. gardeni* are also not absolutely host specific, occurring in mussels, oysters, clams, scallops and one gastropod species, *Umbonium*[14].

In the life-history stages of *P. vicajii* some points need special mention here, in comparison with the corresponding stages obtained by other workers in other species. The number of zoea stages is now known to vary with the species, 5 in *P. maculatus*[15] 4 in *P. ostreum*[16] and *P. pisum*[17] and 2 in *P. veterum*[18], and *P. taylori*.[19] In contrast with these species, *P. vicajii* has only 1 zoea stage. While in *P. vicajii* the carapace of zoea has 3 spines as in *P. maculatus*, there are none in the zoea of *P. ostreum*. In *P. vicajii*, *P. ostreum* and *P. maculatus* the 1st crab stage or the invasive stage is met with in the same host species in which the other growth stages are also found, but in the case of *P. pisum* the invasive stage is known to occur in the clam *Spisula solidula* whereas the rest of the growth stages from hard stage onwards are completed in the main host like the mussel. Another point of some interest is the occurrence of soft shell male in stage II in some pinnotherid species. Males generally do not live beyond the hard stage I as in *P. ostreum*, but in some like *P. maculatus* and *P. vicajii* they live up to soft stage II. Silas and Alagarswami[7] observed a similar stage in *Pinnotheres* sp.

In regard to larval abundance of *P. vicajii* in Mandovi estuary in relation to envionmental conditions, it has been pointed out in the foregoing account that the peaks of their occurrence coincided with periods of high salinity conditions and that they were poorly represented, if not altogether absent, in periods of extremely low salinities. It is pertinent in this connection to note that Beach[20] has found salinity exerting a marked effect on the larval development of *P. ostreum*, embryonic development in that species being not possible in salinities below 15‰, though the adults could tolerate such low salinities. Kruckzrski[21] found that *P. maculatus* in Bogue Sound, North Carolina, all stages were more abundant near the inlets of the sound where the salinities were high.

As regards the effects of *Pinnotheres* on host species observed by various workers, the available information has been reviewed by Silas and Alagarswami[7]. Gill erosion, damage to labial palps, suppression of normal development of gonad and digestive gland due to pressure exerted on the visceral organs by the symbiont in the mantle cavity of the host are some of the adverse effects reported in some species. In most cases, as in the present instance, such damages to host tissues are so infrequent that they cannot be attributed to any definite cause. In *Tapes japonicus* infested by *P. sinensis* the meats were invariably leaner and weighed less than in the non-infested ones. In *Meretrix casta* though there were clear visible damages to the gills, palps, etc., there was no significant difference between the meat weights of infested and non-infested ones[7]. In *Paphia malabarica* infested by *P. vicajii* there is a close overlapping of values in meat weights of infested and non-infested clams. That the bigger weight groups among infested clams have shown slightly lower meat values (Table 2) seems to indicate that prolonged infestation may have some adverse effect on the normal increase in the meat weights.

Barring a few which bring harm by heavy injury to the host tissues and are therefore regarded as parasitic, the pinnotherids in general including *P. vicajii*, are commensalistic in existance in their host organisms.

The pinnotherids themselves are attacked by other organisms, like the entoniscid isopods[22], some sacculinids[23] and a few marine fungi[24] all of which are parasitic and the protozoan, *Zoothaminium*[25] which is epizoic. In the present observations, *Zoothamnium* colonies have often been found attached to the chelipeds and the walking legs.

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