BREEDING SEASON, SEXUAL MATURITY AND FECUNDITY OF THE BLUE CRAB, *Portunus pelagicus* (L.) IN SELECTED COASTAL WATERS IN LEYTE AND VICINITY, PHILIPPINES

Corazon B. Batoy, Josephine F. Sarmago and Bernardita C. Pilapil

Assistant Professor and Research Assistants, Department of Plant Protection, Visayas State College of Agriculture, Baybay, Leyte, Philippines.

Portion of a study on the Biology and Ecology of the Blue Crab, *Portunus pelagicus* (L.) in Selected Coastal Waters in Leyte and Vicinity.

Funded by the Philippine Council for Agriculture and Resources Research and Development.

ABSTRACT

Breeding activity of the blue crab *Portunus pelagicus* (L.) was found to be continuous all throughout the year with peak periods during the first and last quarters of the year. Fluctuations in gonad indices of males and females do not necessarily follow the same pattern because the female can store and keep viable mature spermatozoa in their spermatheca for a period of several months. This may facilitate the production of successive broods without necessitating copulation for fertilization. The reproductive cycle of males peaks slightly earlier in the breeding season than that of females. Start of sexual maturity is indicated at a carapace length slightly below 40 mm and males seem to mature earlier than females. Fecundity ranges from 420,976 to 1,312,238 with a mean of 894,284 for crabs 41-70 mm in length.

No significant correlations were observed between monthly gonad index and monthly means of temperature, dissolved oxygen and water transparency. However, salinity seemed to be one of the most important ecological factors affecting the species' reproductive cycle with higher salinities being favorable for breeding.

Ann. Trop. Res. 9:157-177

KEY WORDS: Blue crab (*Portunus pelagicus* L.) . Breeding. Sexual maturity. Gonad index. Fecundity.

INTRODUCTION

Culture of the blue crab *(Portunus pelagicus* L.*)* which is second in rank to *Scylla serrata* as a good crab food resource and delicacy, is little known. In the Philippines and in other countries, studies on the blue crab are relatively few and investigations on its culture at present are largely based on studies of other crabs.

Various aspects of the biology of *P. pelagicus* in the large Peel-Harvey estuarine system of western Australia have been investigated by Potter et al. (1983). The same authors cited the work of Shinkarenko (1979) on the development of the species' larval stages, and the work of Smith (1982) on its status, potential and biology in south Australia. In India, the annual reproductive cycle of *P. pelagicus* from the southwest coast was determined by Pillay and Nair (1971). Dhawan et al. (1976) studied its ecology and potential fishery in Zuari estuary. In the Philippines, however, no published literature on the blue crab *P. pelagicus* is available except for a preliminary report on the first production of the crab stages at the Southeast Asian Fisheries Development Center by Motoh et al. (1978 as cited by PCARR, 1981) and the report of an on-going study conducted by the Marine Science Institute of the University of the Philippines on its larval development and reproductive biology. This study therefore aimed to investigate the breeding, sexual maturity and fecundity of *P. pelagicus* in an effort to contribute to the meager available knowledge on this species. The study also attempted to correlate the prevailing quantifiable ecological parameters like temperature, dissolved oxygen, and water transparency with gonad index.

MATERIALS AND METHODS

Study Area and Sampling Stations

The study was conducted along the western coast of Leyte and the adjacent northeastern coast of Bohol, Philippines. Three stations were established in the study area, namely: Naungan, Aguinin and Lapinig (Fig. 1). Naungan is located in Ormoc City, in northern Leyte while Aguinin and Lapinig are located across the Canigao Channel in the island group of President Garcia, Bohol. The stations were chosen because they provide constant supply of blue crabs in the local markets.

All three stations have shallow and wide shelves; the substrate varies from sandy to loamy sand in the shore and shallow areas, and from sandy loam to loam in the deeper areas. The location of each station, its direct distance and direction from ViSCA, its vegetation and substratum are described as follows:

Station 1. Naungan, Ormoc City, Leyte.

11°00'80''N, 124°34'36''E. 37 km northwest of ViSCA. Sub-

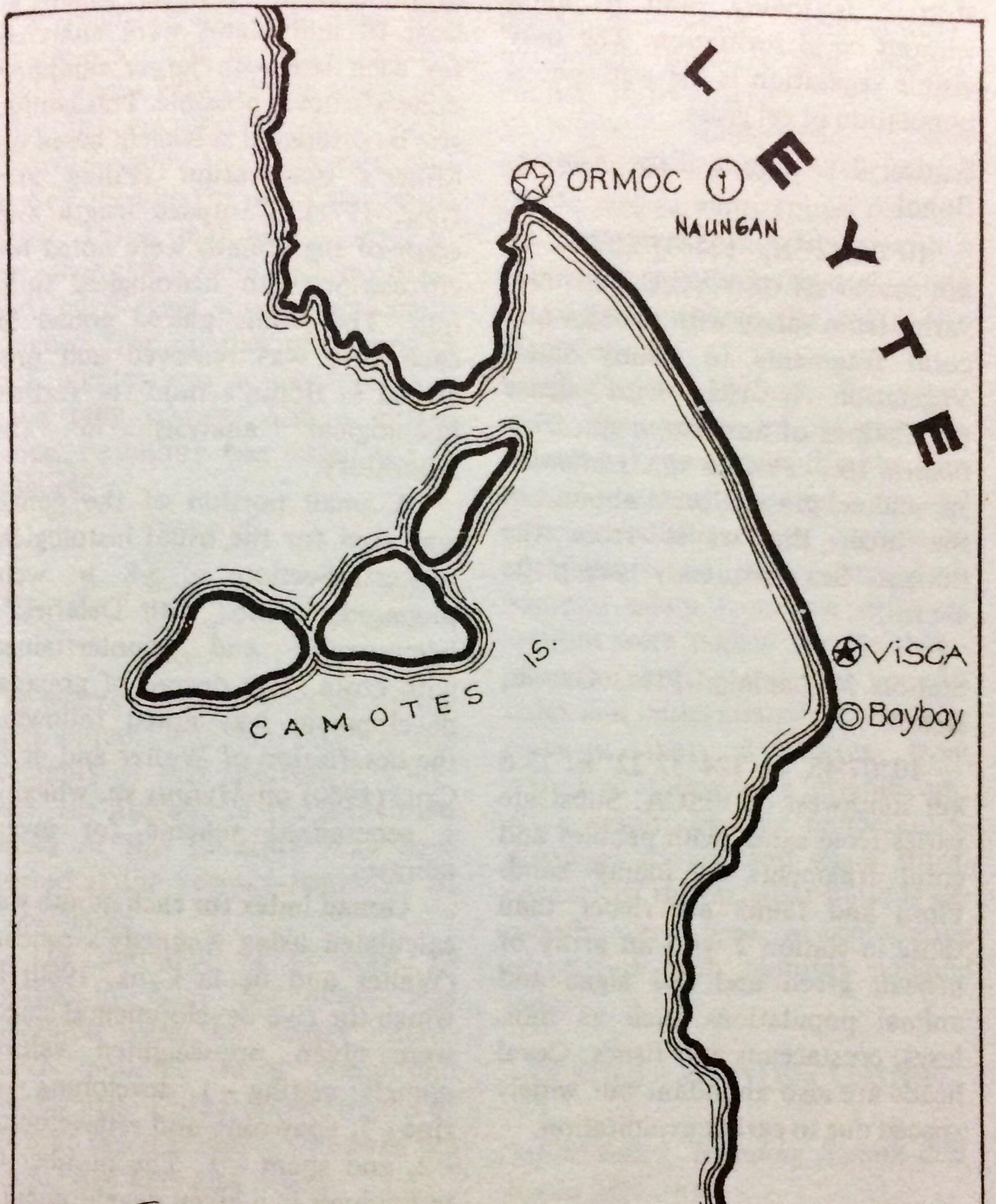

Figure 1. Map of the study area showing the different stations established.

stratum is loamy sand to loam without coral formation. The only visible vegetation is the well-spaced population of eel grass.

Station 2. Aguinin, Pres. Garcia, Bohol.

10°05'42''N, 124°37'20''E. 75 km southwest of ViSCA. Substrate varies from sandy with pebbles and coral fragments to loamy sand. Vegetation is rich with dense populations of *Sargassum* sp., *Turbinaria* sp., *Padina* sp., *Halimeda* sp. and eel grass. Corals abound in the area. Big waves from the Surigao Sea frequently sweep its shores.

Station 3. Lapinig, Pres. Garcia, Bohol.

10°07'48''N, 124°32'22''E. 73.6 km southwest of ViSCA. Substrate varies from sandy with pebbles and coral fragments to loamy sand. Flora and fauna are richer than those in station 2 with an array of brown, green and red algae and animal populations such as molluscs, crustaceans and fishes. Coral heads are also abundant but widely spaced due to earlier exploitation.

Sampling and Analytical Methods

Gonad Index, Breeding Season and Sexual Maturity. Sampling was done from January to November 1983. Monthly samples of both male and female blue crabs were collected from the three stations at the onset of the full moon. The number of specimens analyzed varied with the available catch. However, usually at least 10 individuals were analyzed for each sex with larger sampling done whenever possible. This sample size is considered sufficient based on Miller's observation (Pillay and Nair, 1971). Carapace length and color of the gonads were noted for correlation with histological findings. The whole paired gonad of each crab was removed and preserved in Bouin's fluid for further histological analysis in the laboratory.

A small portion of the gonad was used for the usual histological process. Sections of 5-8 μ were prepared, stained with Delafield's hematoxylin and counterstained with eosin. The degree of gonadal development was noted following the description of Walter and de la Cruz (1980) on *Mytilus* sp. which is a generalized scheme for invertebrates.

Gonad index for each month was calculated using Kennedy's scheme (Walter and de la Cruz, 1980) in which the five developmental stages were given pre-weighted values, namely: resting - 1, developing - 2, ripe - 3, spawning and redeveloping - 2, and spent - 1. The number of individuals in a given developmental stage was multiplied by the weighted value for that stage and the resulting sum of products for all stages was divided by the total number of crabs per monthly sample.

Fecundity. The number of embryos an individual female may carry at one spawning was estimated

using 12 berried blue crabs. The total weight of each egg mass was determined using a Mettler analytical balance with 0.1 mg sensitivity after the eggs/berries have been detached from the pleopods and blotted dry with the use of absorbent paper. Three small aliquots (< 3 g) were then taken from each egg mass and each of these aliquots was again weighed. The number of berries in each aliquot was counted using a hand tally counter and a microscope. Fecundity was computed as follows:

$$\text{Fecundity} = \frac{\text{number of berries in aliquot}}{\text{aliquot weight}} \times \text{total weight of egg mass}$$

The average fecundity value of the three aliquots was then taken as the fecundity of that individual. Likewise, the average of the individual values of the 12 crabs was considered as the average fecundity of *P. pelagicus*.

The diameter of at least 10 berries in each egg mass was measured using an ocular micrometer mounted in a compound microscope. The carapace lengths of the crab samples and the color of the egg masses were also noted.

Determination of Ecological Parameters. Temperature and dissolved oxygen were measured using a portable Hach dissolved oxygen meter. The water sample was collected near the bottom with the use of an improvised water sampler to prevent its contamination with surrounding water. Prior to dissolved oxygen determination, the instrument was first calibrated to the prevailing water temperature, barometric pressure and chloride content of the water.

Water transparency was measured by lowering a standard Secchi disc (a white round plate 30 cm in diameter) into the sea with a rope calibrated in meters and noting the depth at which the white disc disappeared.

Statistical Analysis. To determine the degree of relationship between known quantifiable ecological parameters and gonadal index, product-moment correlation coefficients (r) were computed. Samples taken from the different stations were pooled for the determination of the monthly gonadal index and initial analysis of variance revealed that differences from station to station were insignificant. As a result; average temperature, dissolved oxygen and water transparency of the different stations per month were used in computing correlation with monthly gonadal index.

RESULTS AND DISCUSSION

Gonad Index, Breeding Season and Sexual Maturity

A total of 277 crabs (125 males and 152 females) was used for gonad index determination. The crabs analyzed ranged from 33 to 80 mm in length. The smallest male examined was 37 mm at the spent stage of gonadal development while the smallest female was 33 mm at the developing stage. The different

stages of development are described as follows:

Stage 1. *Resting stage*

Gonads are shrunken, without color, degenerate. Connective tissue is most conspicuous. Sex is almost indeterminate (Figs. 2a and 2b). Few or no follicles present, few residual spermatogonia or oogonia are present in follicles.

Stage 2. *Developing stage*

Early development. Germinal cells are usually scattered throughout the gonads. Follicles are small and few, with spermatogonia and oogonia lining the walls (Figs. 3a and 3b). In males (Fig. 3a), spermatocytes can be seen while in females (Fig. 3b), only a few stalked oocytes and occasional degenerative oocytes are present.

Late development. There is notable increase in gonad size and follicle number as the amount of connective tissue decreases. Genital material is so dispersed throughout the body that it infiltrates even the muscles and connective tissues. Male follicles possess a wide, centripetal band of spermatogonia, spermatocytes and spermatids. The females have numerous free oocytes with many young oocytes still attached to follicular walls.

Stage 3. *Ripe stage*. Figures 4a and 4b

Gonads are very obvious, full of follicles, roundish in shape and protruding from main body mass. Color of genital material is pronounced in both sexes. Connective tissue is hard to find being mostly covered or degenerated. Spermatocyte band is greatly reduced with spermatozoa usually arranged in the lamellae and filling the distended follicles. Spermatozoa are in concentric bands centripetal to spermatocytes, their tails toward the center of the lumen. Sperm plugs may be present. Oocytes are enlarged and usually free in the lumen of filled follicles.

Stage 4a. *Spawning stage*.

There is concurrent reduction in size of gonad and of areas infiltrated by genital tissue. Follicles are shrunken, reduced in number and contain less genital products; these may even be empty except for layers of primary sex cells. Male follicles exhibit large fissures or flowing streams throughout the lumen (Fig. 5a). In females, free oocytes usually line the follicular walls (Fig. 5b). Stalked oocytes are present at times.

4b. *Redeveloping stage*. Figures 5c and 5d

Connective tissues are usually abundant. Follicles are smaller and do not fill the gonad. Gametogenesis begins anew with the formation of a thick layer of spermatocytes along follicular walls. Lumen is usually free of sex products. In females; many young, attached oocytes and a few free, unspawned oocytes are still present. Sex differentiation based on color is still possible. This stage is at times easily confused with stage 2; however when redevelopment is complete, follicles are not as fully packed.

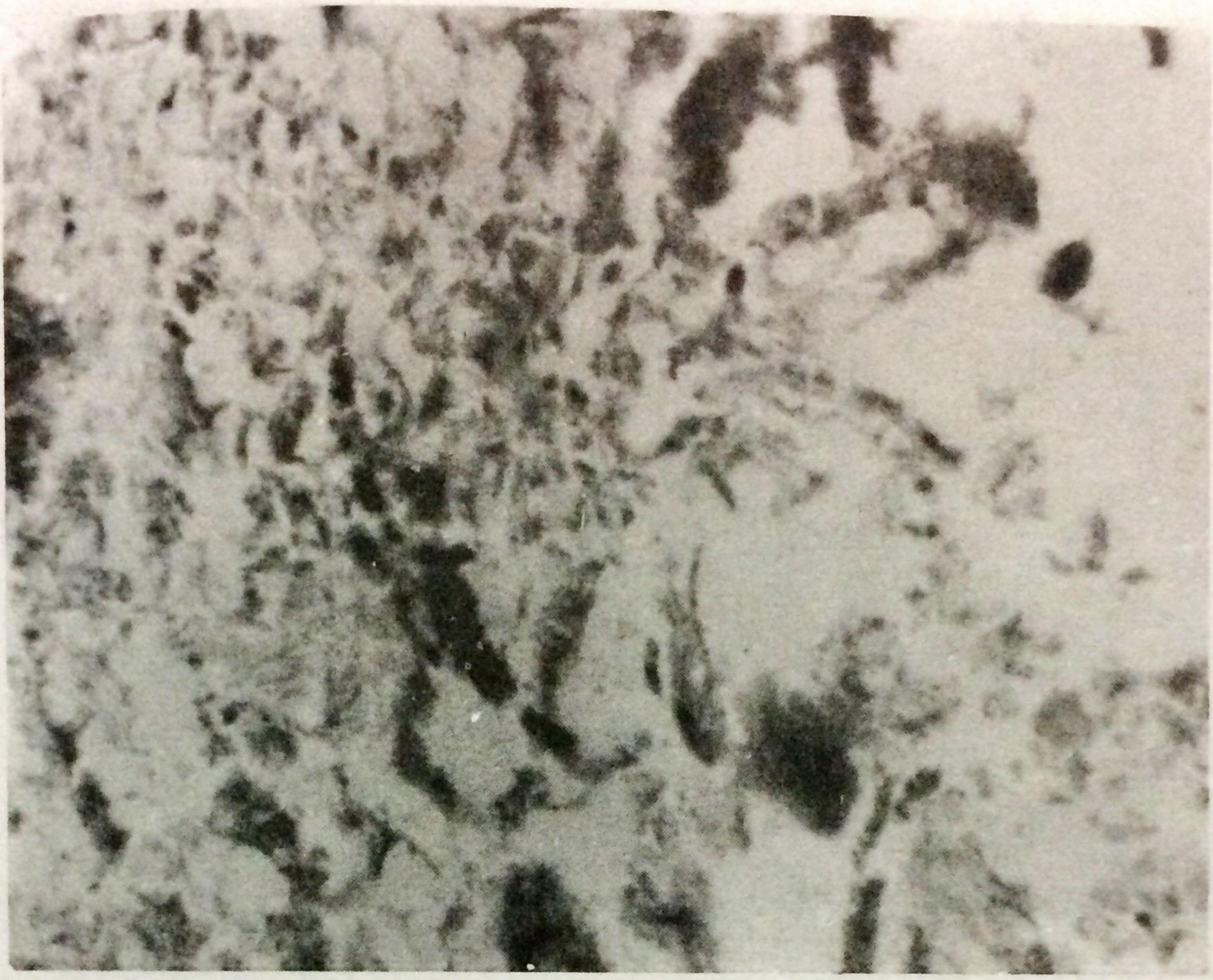

Figure 2a. Resting stage of male *Portunus pelagicus*. 400x

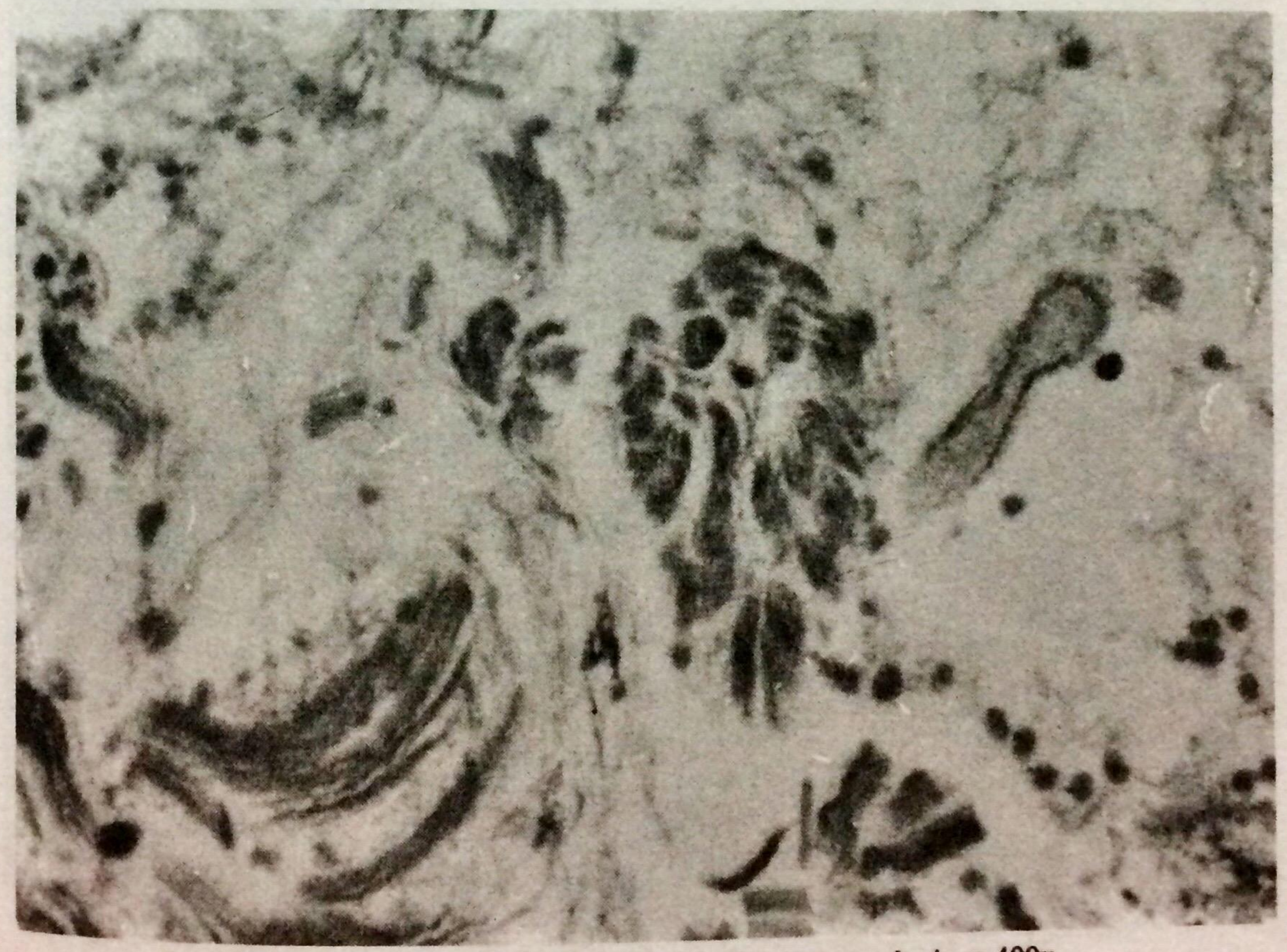

Figure 2b. Resting stage of female *Portunus pelagicus*. 400x

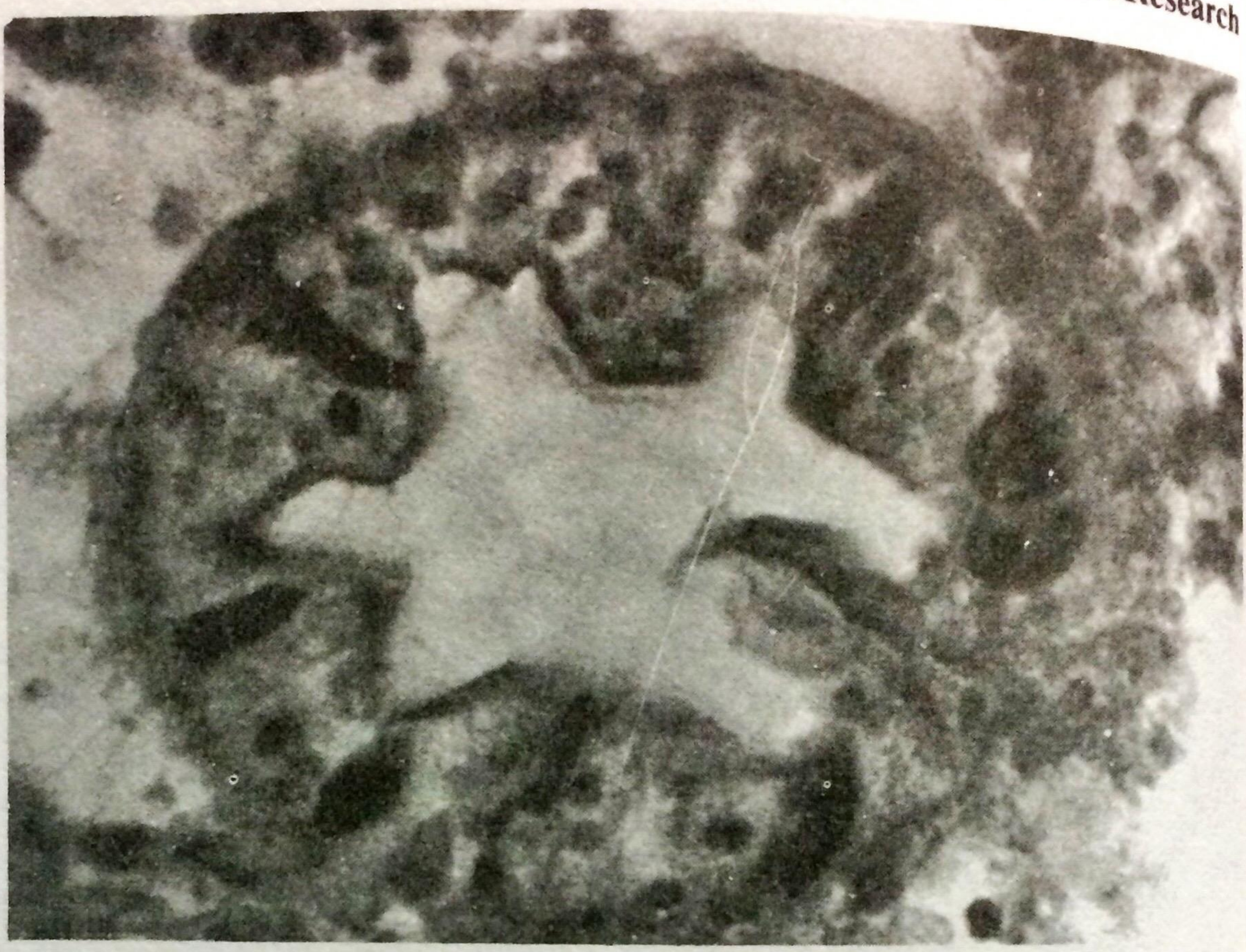

Figure 3a. Developing stage of male *Portunus pelagicus*. 400x

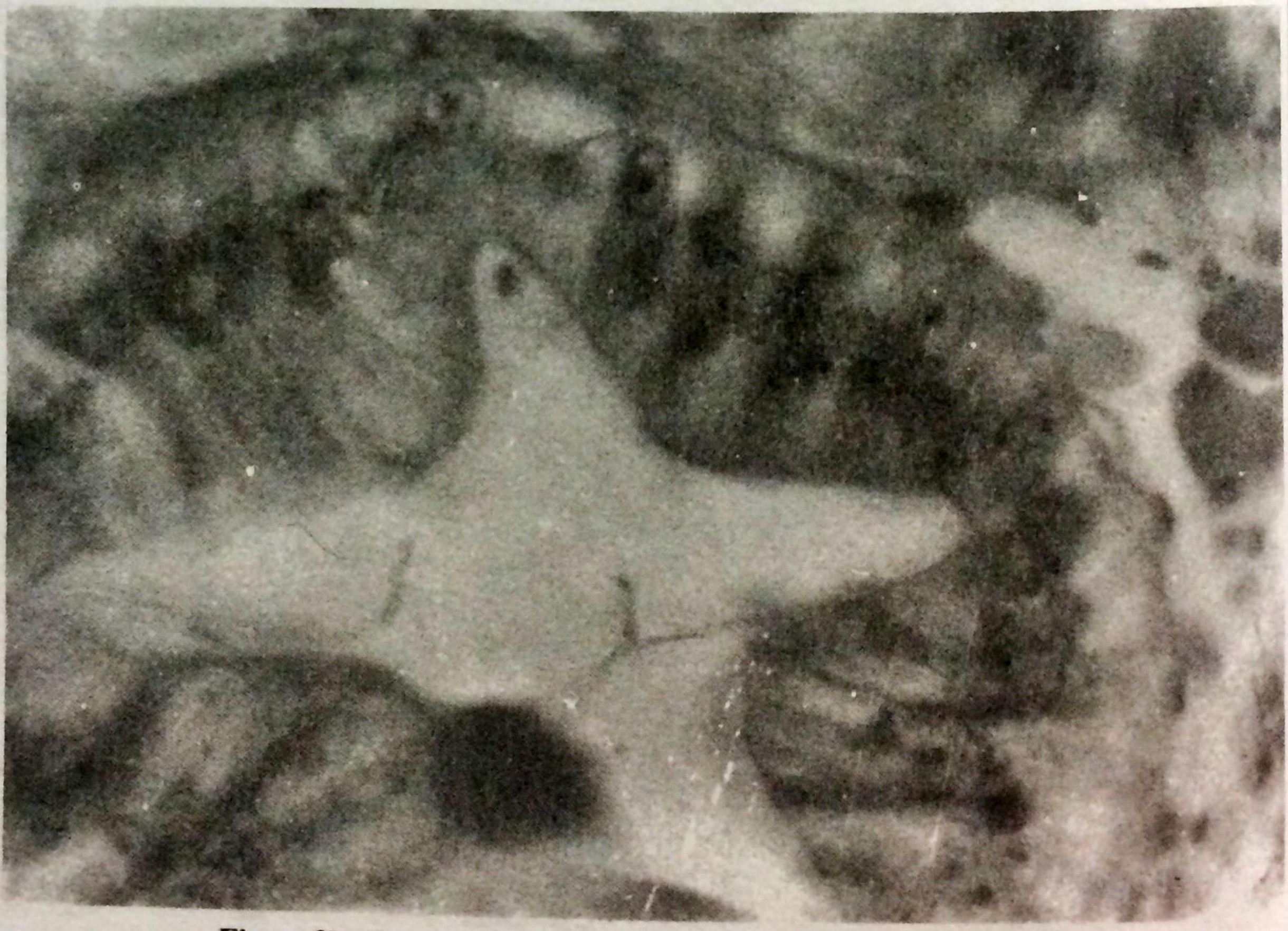

Figure 3b. Developing stage of female *Portunus pelagicus*. 400x

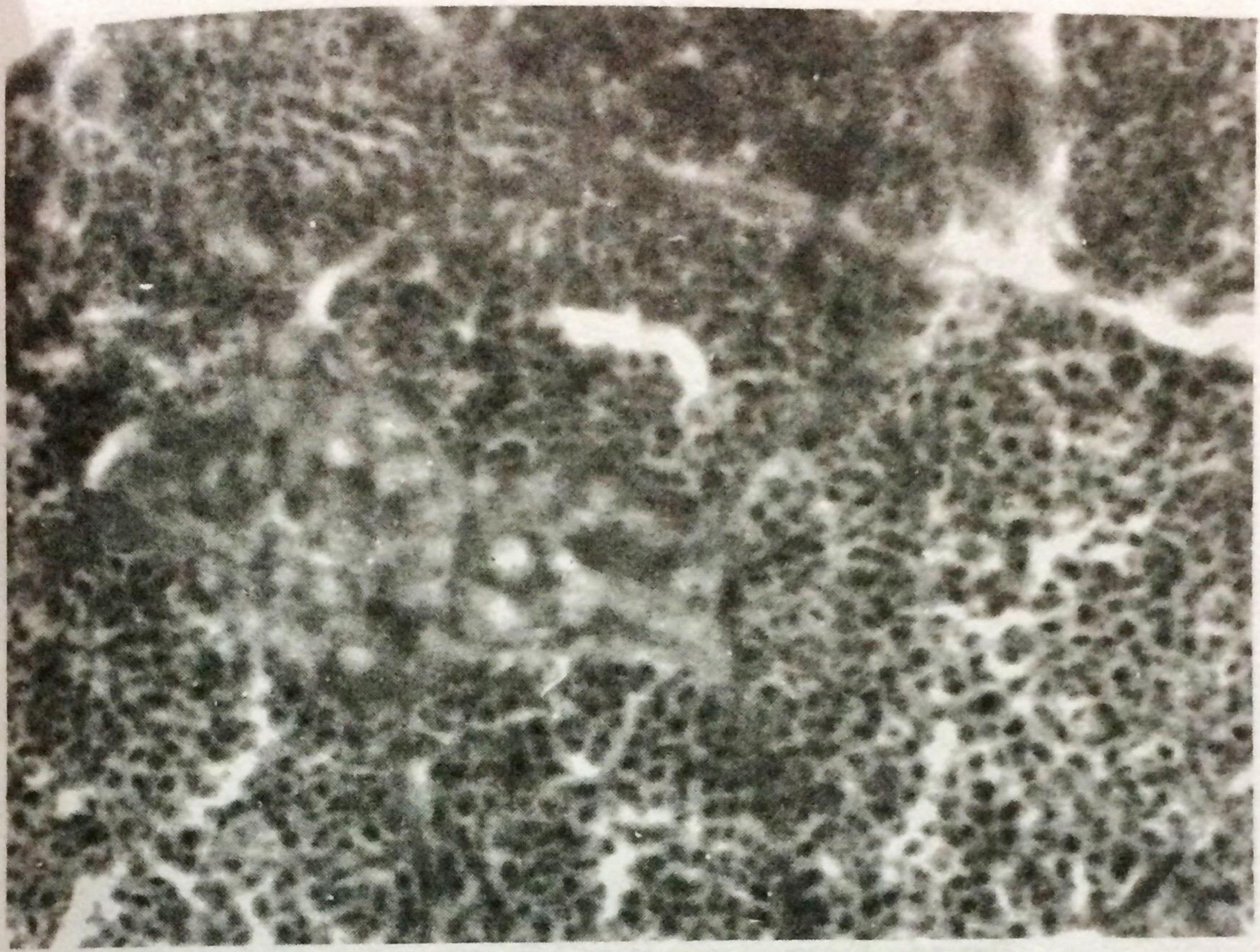

Figure 4a. Ripe stage of male *Portunus pelagicus*. 400x

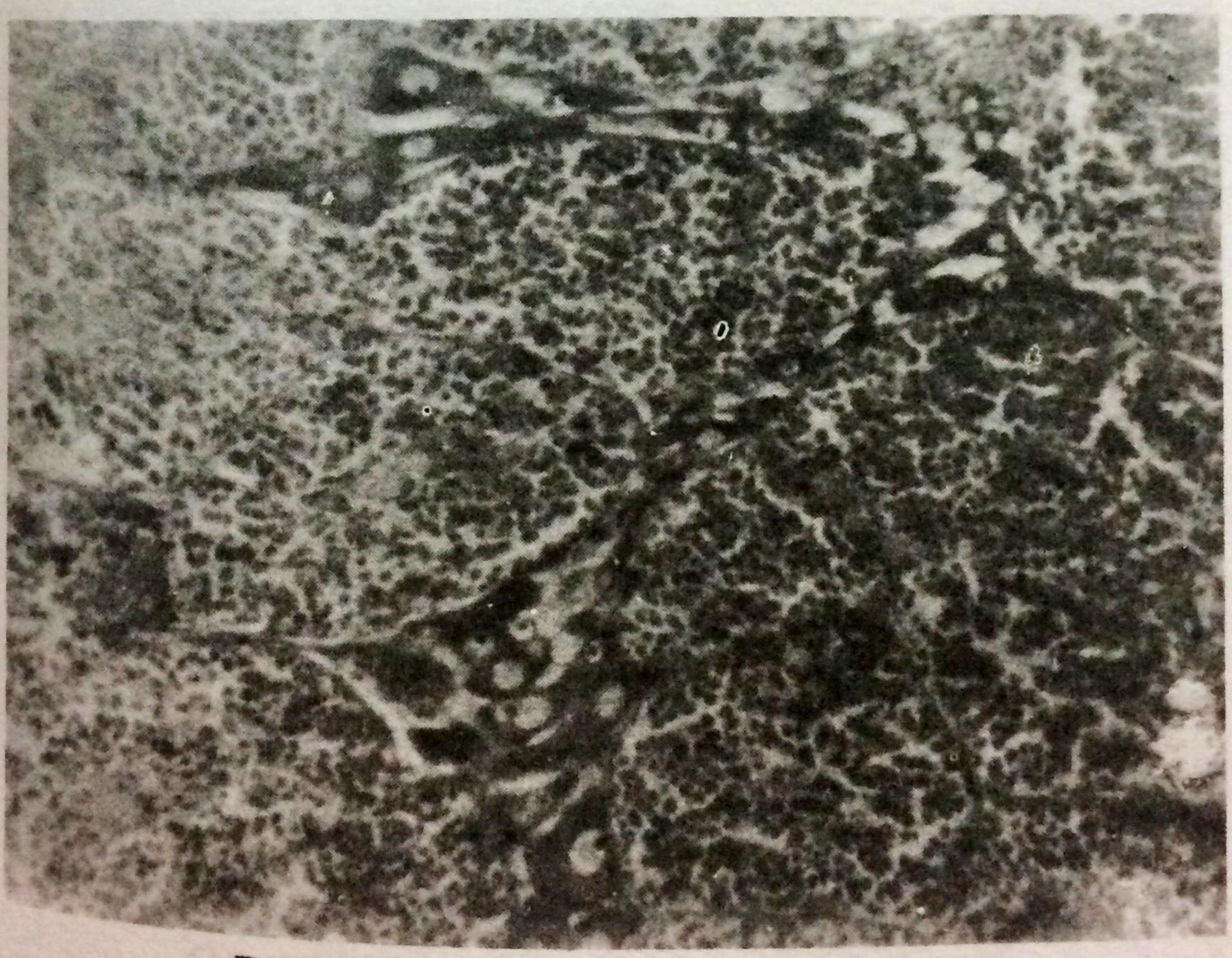

Figure 4b. Ripe stage of female *Portunus pelagicus*. 100x

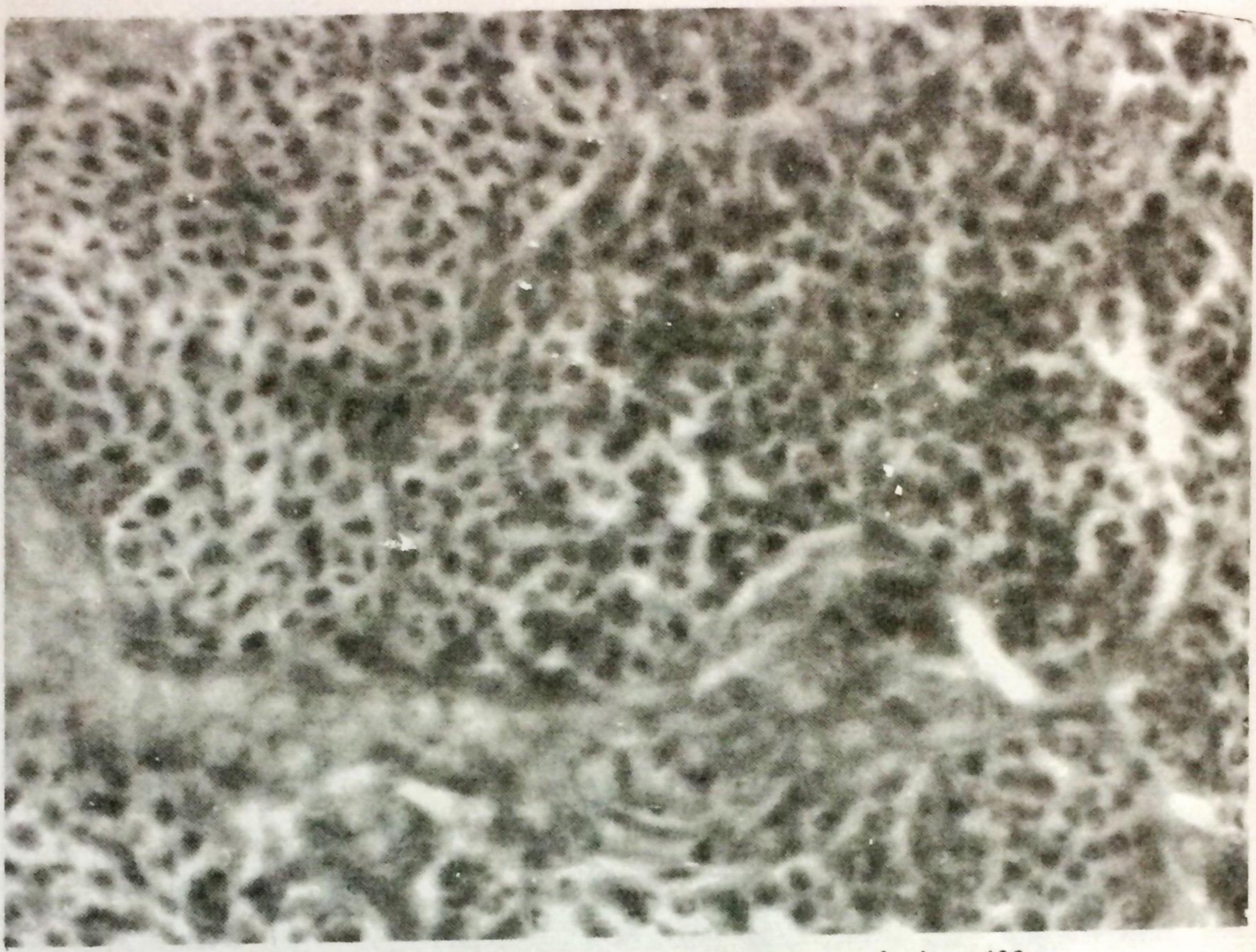

Figure 5a. Spawning stage of male *Portunus pelagicus*. 400x

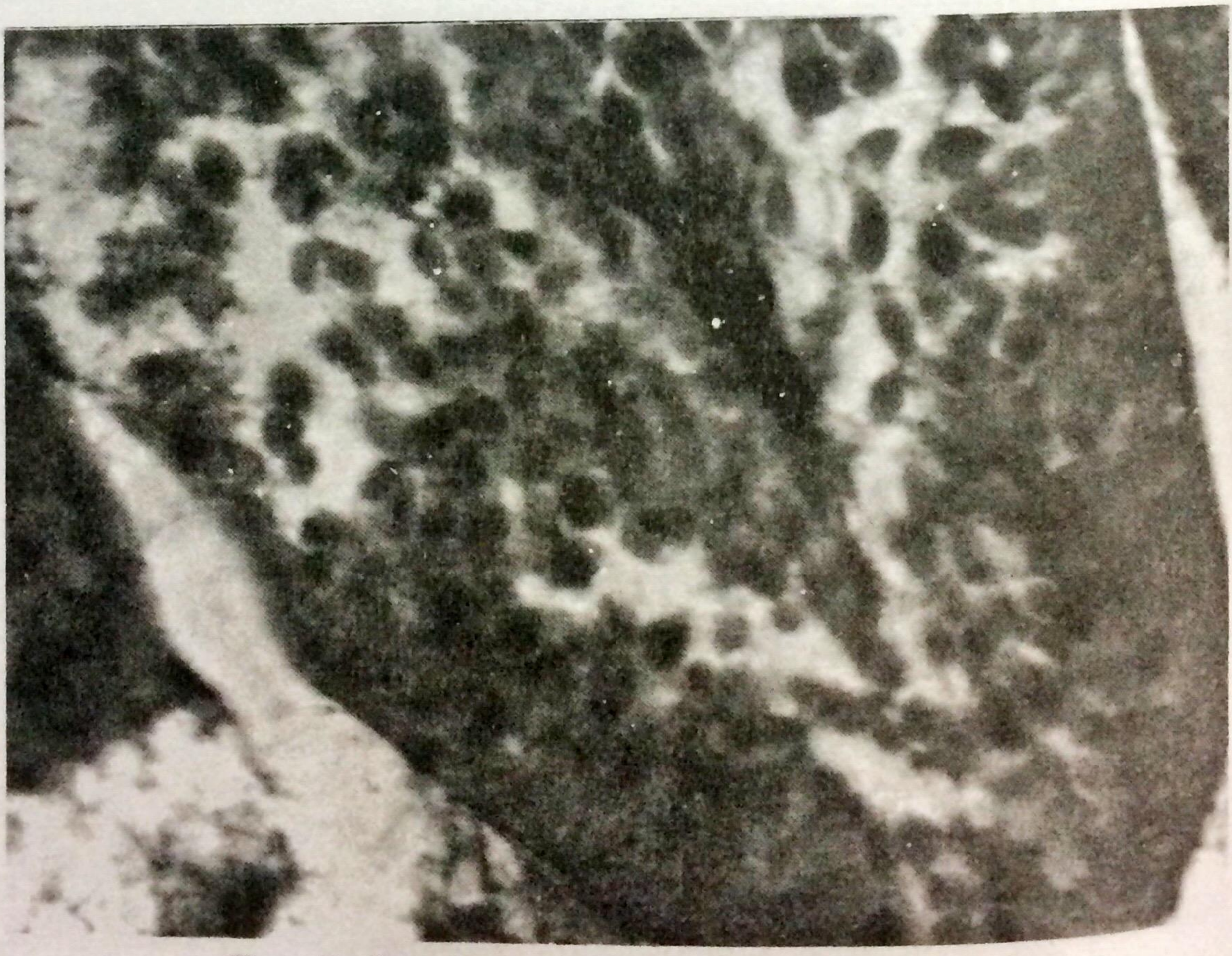

Figure 5b. Spawning stage of female *Portunus pelagicus*. 400x

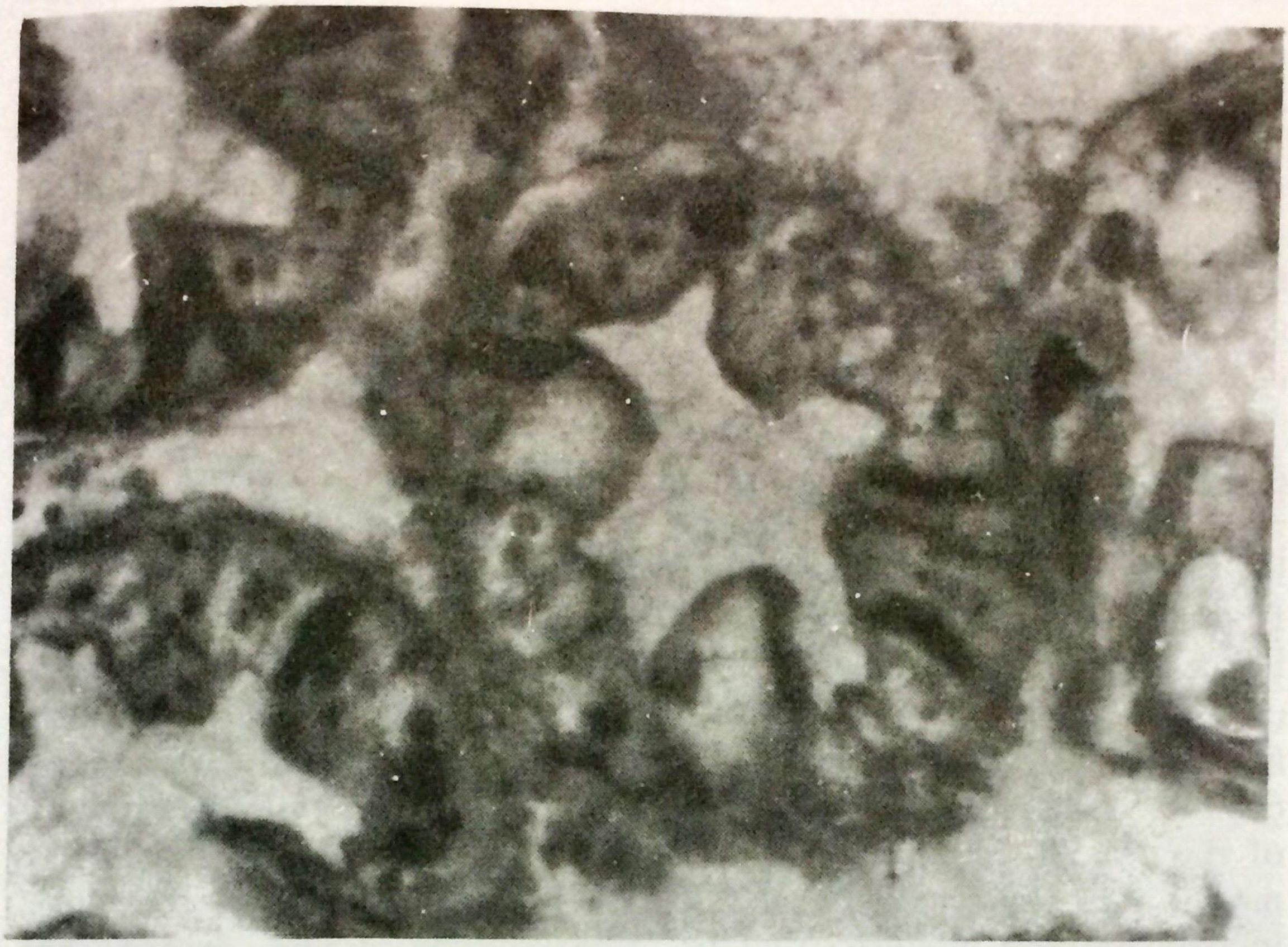

Figure 5c. Redeveloping stage of male *Portunus pelagicus*. 400x

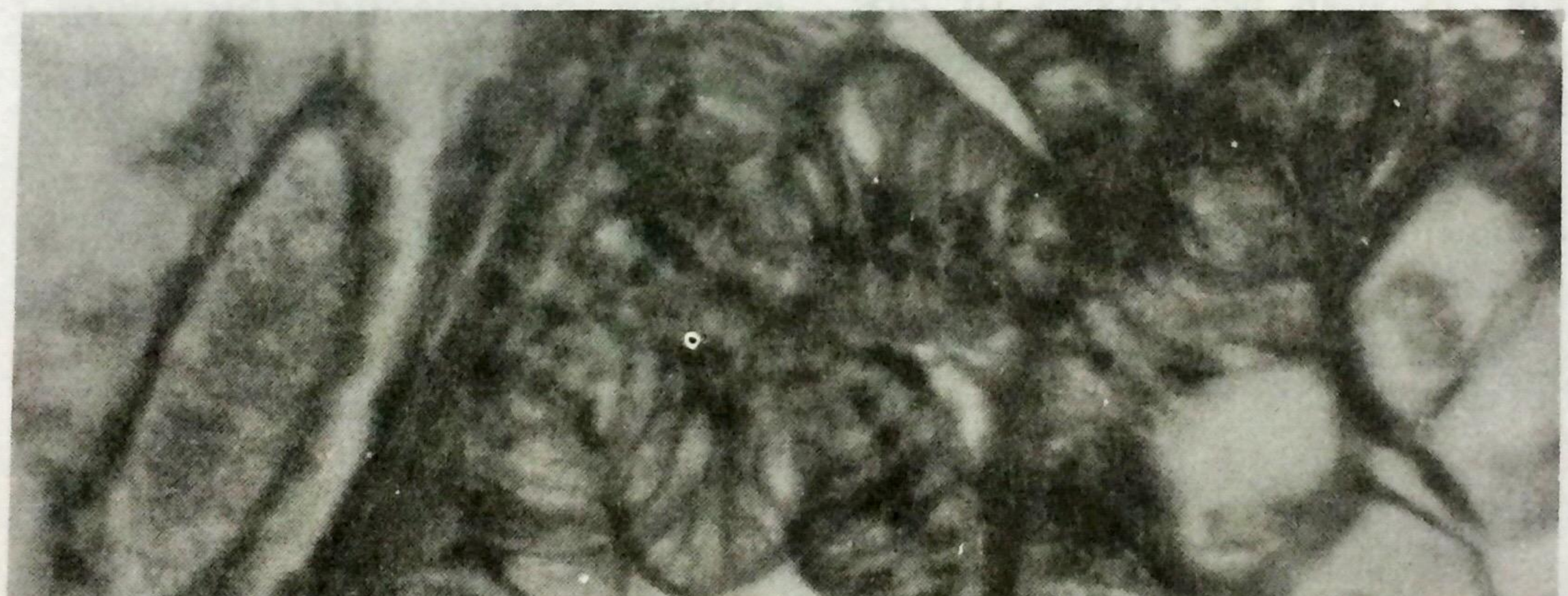

Figure 5d. Redeveloping stage of female *Portunus pelagicus*. 400x

Stage 5. *Spent stage.*
Figures 6a and 6b

This stage is almost identical to and may be confused with stage 1. Follicles are collapsed and degenerate but the lumen contains large amounts of cellular debris.

Figures 7-9 show the percentage distributions of gonadal development stages of female, male, and both sexes of *P. pelagicus* collected from the study area. It can be noted that gametogenic activity takes place throughout the year. Ripe, spawning and/or redeveloping individuals could be encountered at all months of the year. There is not a single month except in males when all individuals were in the resting or spent stage.

For the female population (Fig. 7), high percentages of ripe individuals were observed in February, May and November (30.8% in February and May, and 28.6% in November). This coincides with months of high gonadal indices (Fig. 10) for February and November but not for May. The gonad index for May was relatively low due to the absence of spawning and/or redeveloping individuals in the sample.

For the male population, no ripe individuals were observed all throughout the sampling year (Fig. 8). It could be by sheer chance that no ripe males were included in the sample but this could probably be a limitation of the sampling time which was at the onset of the full moon. Warner (1977) described breeding in tropical crabs to be often continuous throughout the year but it may show a lunar rhythm in which egg hatching coincides with full or new moon. If this is so, it is possible that a high percentage of ripe males could be found at early or the middle part of the lunar cycle since a high percentage of the males sampled at the onset of the full moon was already at the spawning and/or spent stages. Moreover, this absence of ripe males in the sample may suggest that once the male has started to ripen, it may copulate even if not all of its follicles are mature. This is supported by the histological finding that some males have both ripe and spawning/redeveloping stages within one mesosoma with the latter stages having higher percentage. Another evidence to substantiate this contention is the presence of 5-20% sperm plug in some redeveloping males. Pillay and Nair (1971) also reported that gonad indices of males are not clearly indicative of the duration of the breeding season.

Spawning commonly occurs in most months with intense periods in January, April, July and October (Fig. 9). Likewise, redevelopment also takes place throughout the year with January and November being the periods of very active redevelopment. The resting and spent stages were also common in most months with the spent stage showing the highest percentage among the developmental stages.

Percentage distributions of gonadal development stages are

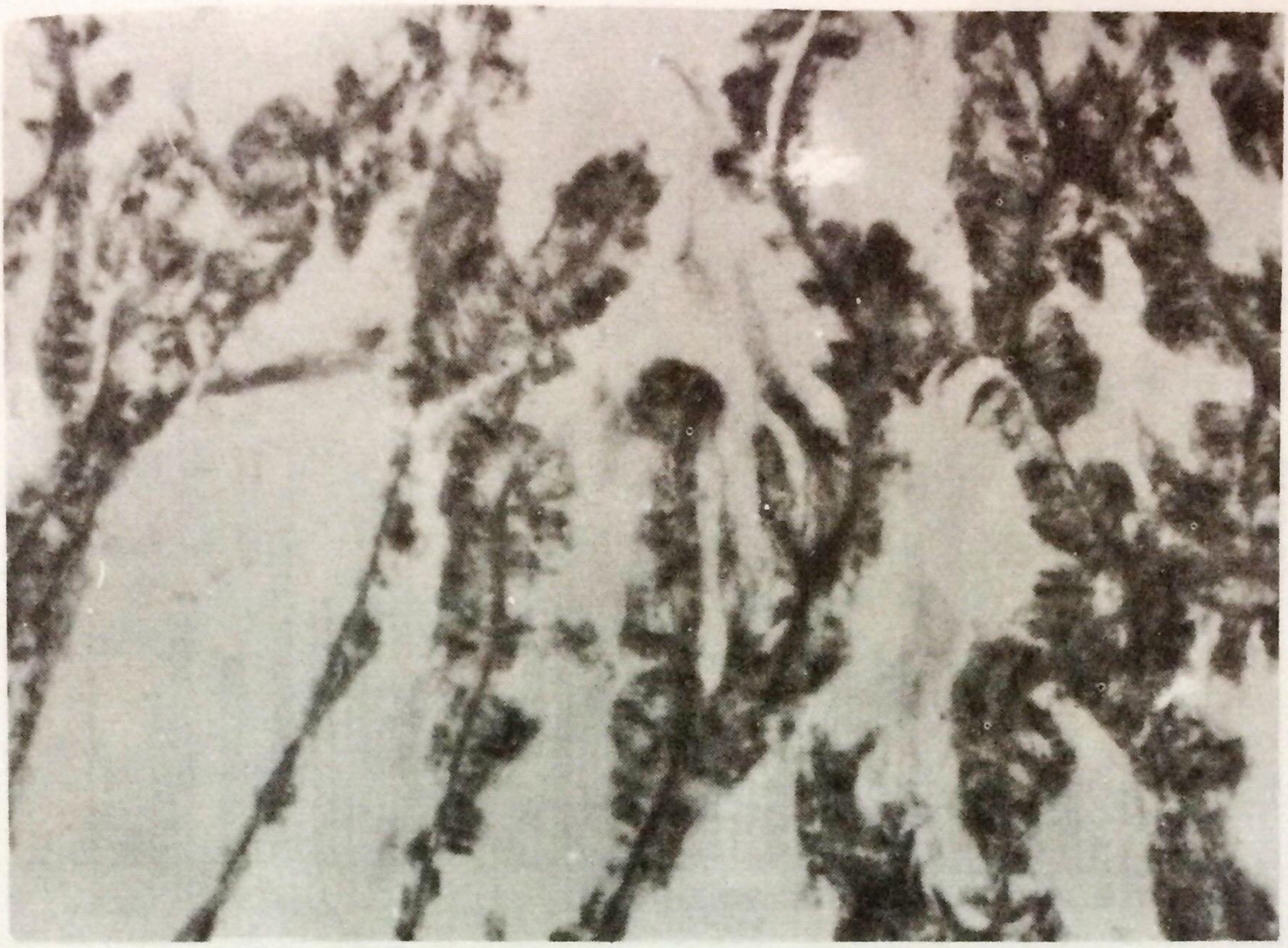

Figure 6a. Spent stage of male *Portunus pelagicus*. 100x

Figure 6b. Spent stage of female *Portunus pelagicus*. 100x

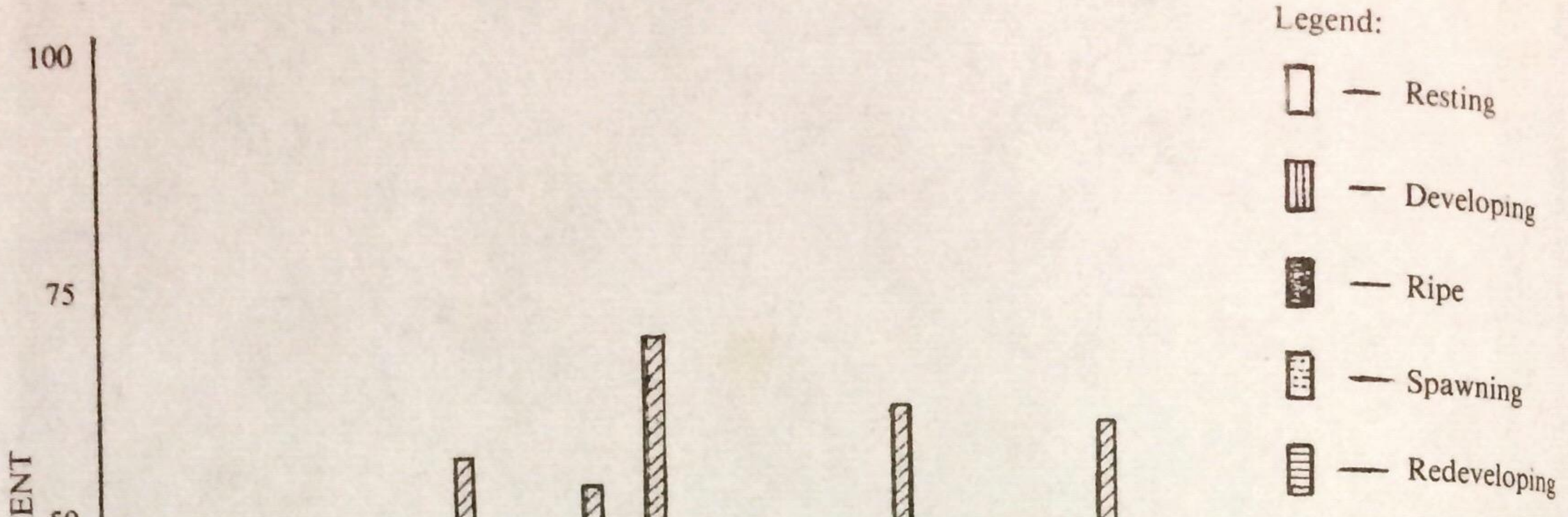

Figure 7. Percentage distribution of gonadal development stages of female *Portunus pelagicus* collected from Leyte and Bohol from January to November 1983.

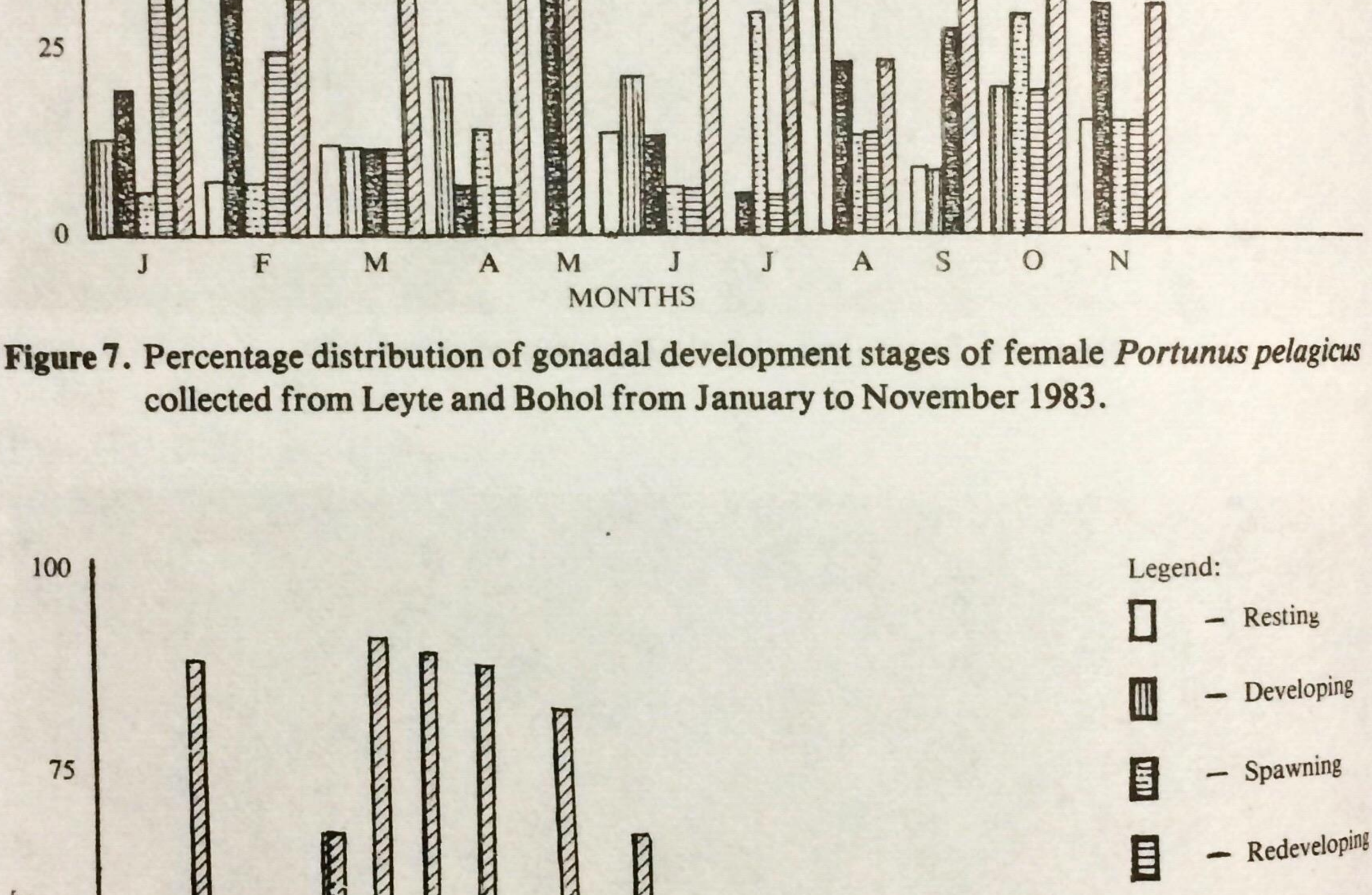

Figure 8. Percentage distribution of gonadal development stages of male *Portunus pelagicus* collected from Leyte and Bohol from January to November 1983.

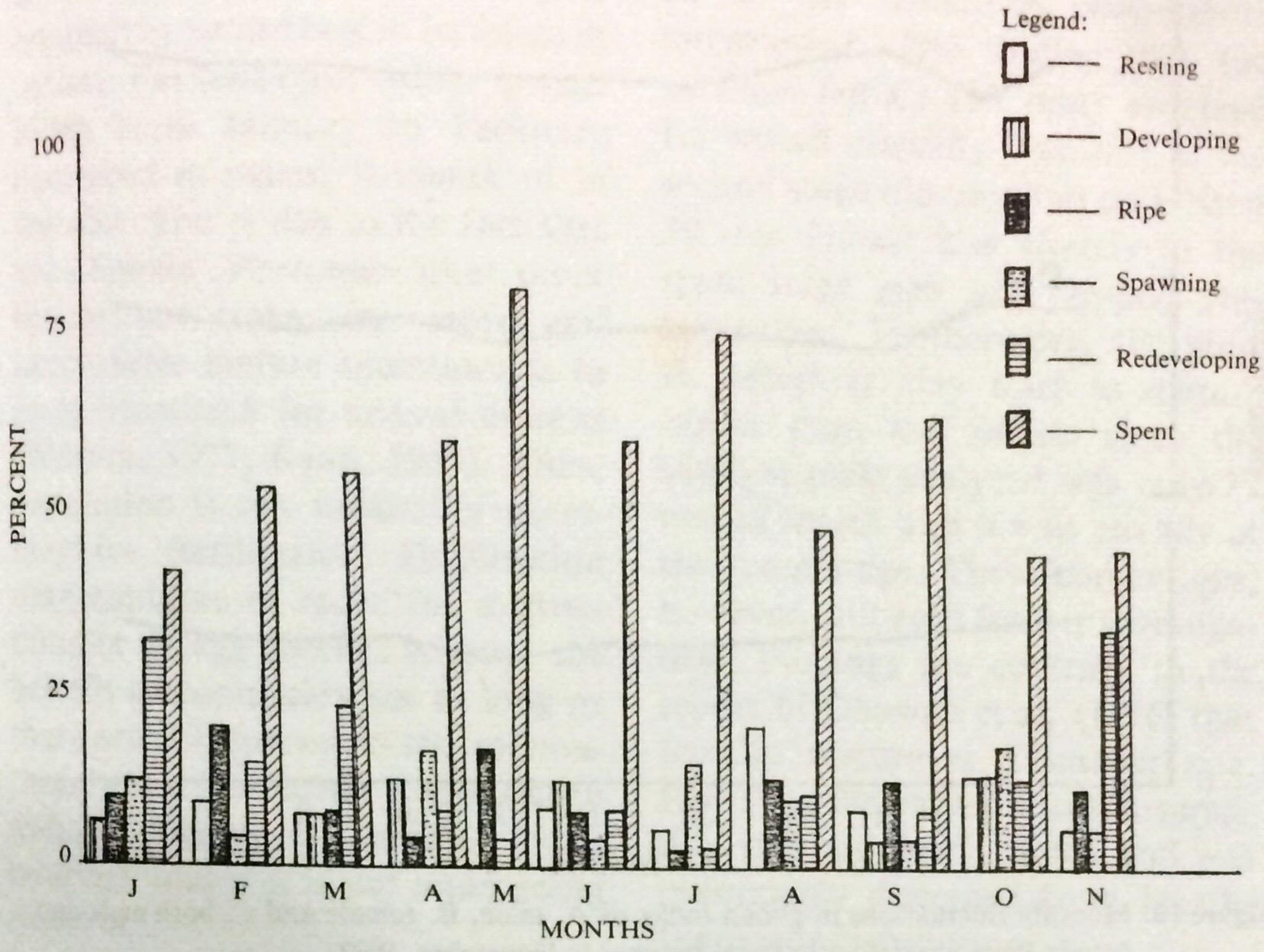

Figure 9. Percentage distribution of gonadal development stages of both sexes of *Portunus pelagicus* collected from Leyte and Bohol from January to November 1983.

useful in assessing the reproductive condition of a population at a certain time but they should not be used as the only basis. The gonad index should also be considered since it measures the average reproductive condition of the population in question. Percentage distributions of gonadal stages also serve to prove homogeneity or heterogeneity of breeding habits. In this study, heterogeneity of the breeding population has been proven, i.e. while some individuals are in the earlier stages of maturation, others may either be already ripe, spawning and/or redeveloping, or already spent.

The monthly variations in gonad index of male, female, and both sexes of blue crabs in the study area from January to November 1983 are shown in Figure 10. In general, a rise in gonad index indicates gametogenesis while a fall indicates spawning (including redevelopment and further spawning). For females, peak periods were observed during the first and last quarters of the year, the highest value (1.92) occurring in February. Peak periods occurred at approximately the same time for males and for the total population. However, the highest gonad index for males (1.50) was noted in January and March while it occurred in January for the total population. The second and third quarters of the year were periods of relatively low gonad indices suggest-

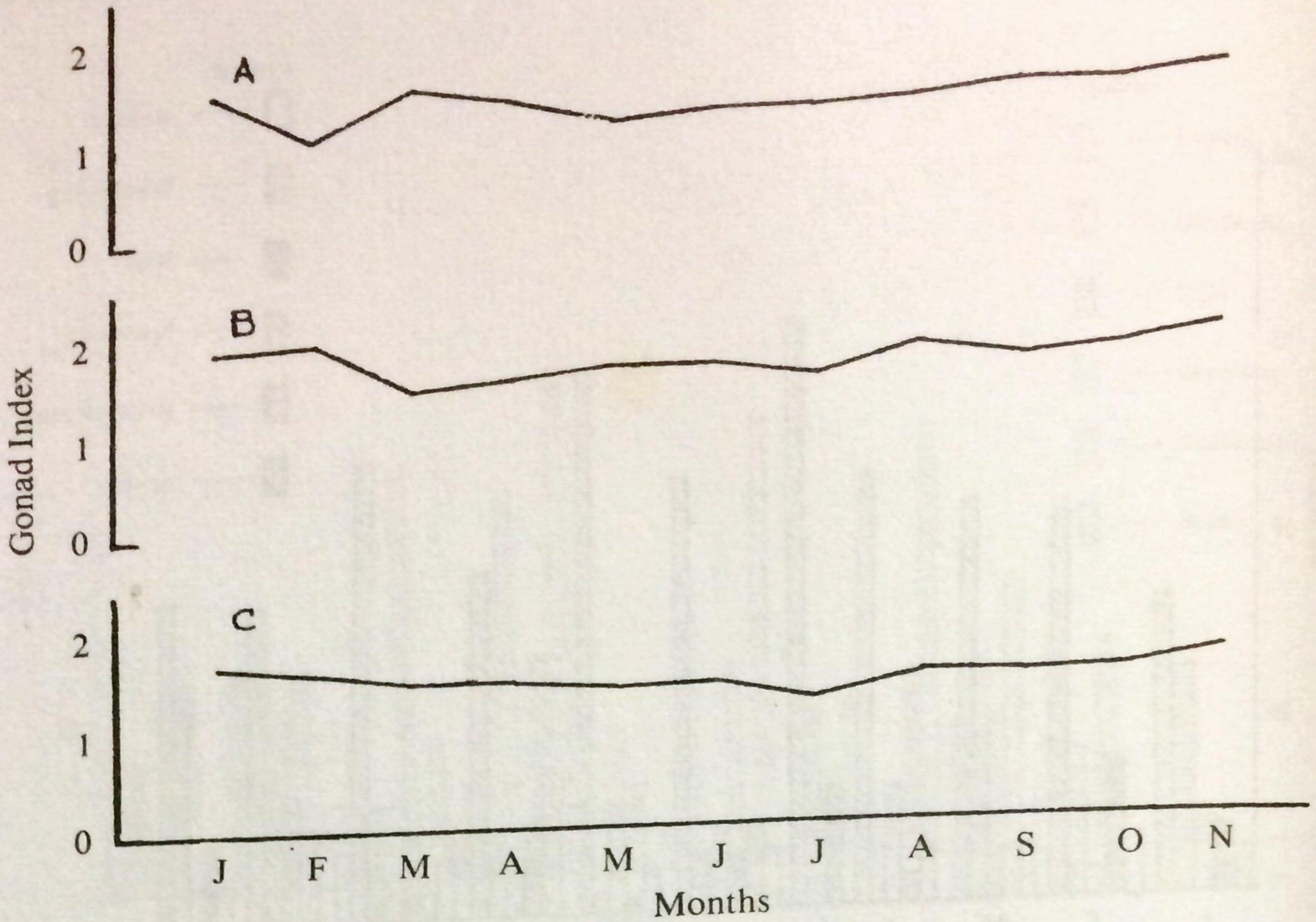

Figure 10. Monthly fluctuations in gonad index of A. male, B. female and C. both male and female *Portunus pelagicus* from January to November 1983.

ing a generally spawned-out condition for the males, females and the total population. If the study was continued in the succeeding year, the breeding season might have extended from the last quarter of the year to the first quarter of the succeeding year as has been found by Pillay and Nair (1971) and Dhawan et al. (1976) in *P. pelagicus* and by Ryan (1967) in *P. sanguinolentus* (a species occupying the same habitat and often caught along with *P. pelagicus)*.

Pillay and Nair described breeding in *P. pelagicus* from the southwest coast of India not to be continuous all year round but to extend over a nearly 9-month period from August to April with maximum gonadal activity during December/January. In this study, breeding was continuous throughout the year and this agrees with Warner's (1977) description for tropical crabs and with Ryan's (1967) finding for *P. sanguinolentus* in Hawaii. The presence of ripe and spawning individuals throughout the year as shown by the percentage distribution of the gonadal development stages (Fig. 9) could support this. Percentage distributions of the different gonadal stages were, however, not included in Pillay and Nair's work as their gonad indices were primarily based on the ratio of gonad weight to body weight.

Fluctuations in gonad indices of males and females did not necessarily follow the same pattern (Fig. 10). An increase in the gonad index

of the female was not necessarily coupled by an increase in its value in males. For instance; while gonad index from January to February decreased in males, it increased in females. This is due to the fact that the female *Portunus* like other brachyuran crabs, can store and keep viable mature spermatozoa in its spermatheca for several months (Warner, 1977; Ryan, 1967). Thus, copulation is not invariably necessary for fertilization. Fertilization may continue to recur for a given number of egg batches without the benefit of copulation for as long as there are still sperms in the spermatheca when the female is ripe (when mature oogonia are present in its ovaries), and if it is not undergoing molting.

It can be noted in Figure 10, that the first peak of gonadal activity in males was in January while that in females occurred in February. This non-concurrency of the male and female reproductive cycles also supports the finding of Pillay and Nair (1971) that the peak of the reproductive cycle of males occurs slightly earlier in the breeding season than that of females. However when the gonad indices of both sexes reach a peak together, this may indicate the time when reproductive activities are at its peak.

Results suggest that the female *Portunus* starts to mature sexually at a carapace length slightly below 40 mm. This was based on the field observation that the smallest berried females caught had carapace length of about 40 mm which was confirmed by the fishermen cooperators interviewed. The finding that the smallest female (33 mm) analyzed for sexual maturity was only at the second stage (developing) and that a 39 mm female was already in the spent stage may also support this contention. Furthermore, the male *P. pelagicus* may start to mature earlier than the female since the smallest male analyzed was only 37 mm in length and it was already at the spent stage. These contentions, however, still need further investigation. Findings are contrary to the report of Dhawan et al. (1976) that females mature at a smaller size. However, the basis for such assumption was not clearly stated and was presumably discerned from length-frequency distribution.

In general, sexual maturity of blue crabs is characterized by the loosening of the abdominal flap (Van Engel, 1958 as cited by Potter et al., 1983). In males, this can be detected by opening the abdominal flap. Males which are sexually mature have their first pair of pleopods extended/separated from the others. As already known. the first pair of pleopods in male crabs functions not for swimming but as an organ of intromission for sperm transfer. In females, maturity can be detected by the broadening of the abdomen. Immature females have elongate abdomens which adhere to the ventral portion of the crab. The broadening of the abdominal flap facilitates the holding of the berries (Ryan, 1967).

Fecundity

The carapace length; approximate number, color and diameter of eggs of *P. pelagicus* analyzed for fecundity are shown in Table 1. The number of eggs produced per ovulation is very large and varies with the size of the crab and between females. The trend is for larger crabs to produce more eggs than smaller ones as suggested by Warner (1977). This trend was also observed in this study. Table 1 shows that the small crabs (40.6-45.5 mm) included in fecundity analysis also had low number of berries while the large ones (65.6-70.5 mm) had higher fecundity values.

Fecundity ranged from 420,976 to 1,312,238 with a mean of 894,284 for crabs ranging from 41 to 70 mm in length. This is rather higher than the findings of Potter et al. (1983) with a mean of 509,433 eggs based on 18 females ranging from 102 mm to 136 mm in width. However, their specimens were taken from an Australian estuary with wide seasonal fluctuations in temperature and salinity. This might have affected the reproductive capacity of *P. pelagicus* from the estuary as the same authors provided strong evidence that these blue crabs prefer salinities between 30-40‰. Nevertheless, the present findings approximate the results obtained by Ryan

Table 1. Approximate number, color, and diameter of eggs of *Portunus pelagicus* 41 to 70 mm in length.

Carapace Length Classes (mm)	No. of Crabs	Approximate No. of Eggs	Color of Eggs	Diameter of Eggs
40.6 - 45.5	2	420,976 - 599,359	dark orange	0.25 - 0.28
45.6 - 50.5	3	684,302 - 736,886	brownish yellow to light orange	0.28 - 0.325
50.6 - 55.5	2	989,616 - 1,090,976	orange to dark orange	0.25 - 0.30
55.6 - 60.5	2	985,299 - 1,111,426	brownish yellow	0.30 - 0.35
60.6 - 65.5	2	1,056,513 - 1,058,395	light orange	0.28 - 0.32
65.6 - 70.5	1	1,312,238	light orange	0.28 - 0.32

(1967) in *P. sanguinolentus*. The estimated number of eggs of four mature females in Ryan's report varied from 960,000 to 2,250,000. Tressler and Lemon (1951) reported that fecundity in a mature *Callinectes sapidus* (American blue crab) ranged from 1,750,000 to 2,000,000; while *Scylla serrata,* a relatively well-studied portunid crab in the Philippines produced nearly 2,000,000 eggs at full-grown (large enough but not the maximum) size (Arriola, 1940; Ong, 1966; Escritor, 1970; and Varikul et al., 1970).

The color and size of the berries may well indicate its 'age'. Newly-laid berries are dark orange (yolky) in color and slightly oval in shape with a maximum diameter ranging from 0.25-0.35 mm (Warner, 1977). As the embryos develop, the color of the berries change through brown to dark green as the yolk is used up. The berries swell as they develop and are nearly double their newly-laid volume by the time they are ready to hatch. Table 1 shows that the berries analyzed were either newly laid (dark orange) or just a few days old after having been laid (light orange to brownish yellow). The diameter range of the berries also support this observation. The eggs observed were not ready to hatch as they were neither greenish gray nor were they relatively large.

Ecology and Interaction

Figure 11 shows the monthly fluctuations in dissolved oxygen content, temperature and water transparency of the different stations. The range of fluctuation in temperature was quite narrow with minimum and maximum readings at 26.5 and 30°C, respectively. This is not surprising because changes in environmental conditions are less pronounced in the tropics.

Similarly, fluctuations in dissolved oxygen content were not so pronounced with minimum and maximum readings at 4.9 and 9.5 mg/L, respectively. Water transparency ranged from 6 to 15.5 meters.

The factors which influence the breeding, sexual maturity and fecundity of *P. pelagicus* may be endogenous, exogenous or an interaction of both factors. Moreover, exogenous factors may consist of the physico-chemical and/or biological conditions of the environment.

The physico-chemical parameters studied, namely; temperature, water transparency and dissolved oxygen content, showed slight correlations with monthly gonadal index fluctuations but these were not significant. This may be because the monthly variations in these parameters were quite narrow so as to depict any obvious correlation with monthly fluctuations in gonad index. Blue crabs are able to withstand considerable variations in temperature. Dhawan et al. (1976) reported a tolerance range of 25-40°C. Furthermore, Pillay and Nair (1971) indicated that although temperature affects breeding of marine animals, it is not the sole

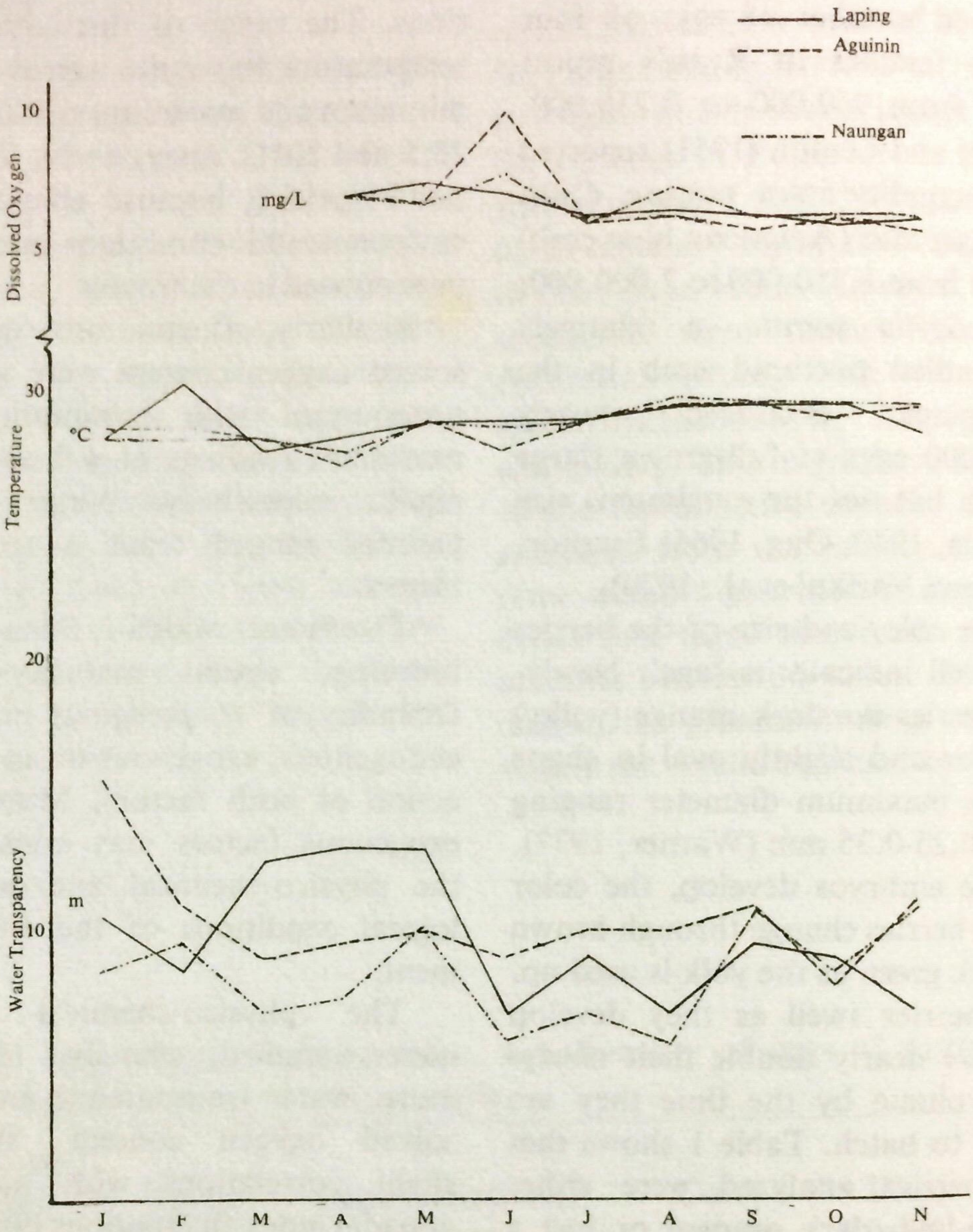

Figure 11. Monthly fluctuations in dissolved oxygen content, temperature and water transparency of the different stations from January to November 1983.

influencing factor. They suggested that the factors controlling the reproductive cycle of *P. pelagicus* may probably be the favorable salinity conditions and the availability of planktonic food for the larvae. Moreover, they reported that monsoon months which are characterized by low salinities due to heavy rainfall and river run-off, are unfavorable for breeding. Although salinity was not investigated in this study, it is interesting to note that the months of low gonadal indices (Fig. 10) coincided with southwest monsoon months (June to October) in this area (Pers. comm. with local weatherman). This could have been a cause of the lowered gonadal indices during these months. The availability of planktonic food was not investigated in this study.

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