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POPULATION BIOLOGY OF *XIPHOPENAEUS KROYERI* (HELLER 1862) (DECAPODA: PENAEIDAE) FROM UBATUBA BAY, SÃO PAULO BRAZIL

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ABSTRACT The population structure and abundance of *Xiphopenaeus kroyeri* (Heller, 1862) were analyzed during monthly samples from October 1992 to September 1993 in Ubatuba Bay (23°26'S and 45°02'W), Brazil. Sampling was carried out at two parallel transects: one of them located in its midregion and the other at the mouth of the bay. After trawling, shrimps were separated from other benthic organisms, sexed, and counted. Their total length was also measured, and the degree of gonadal development was assessed. *Xiphopenaeus kroyeri,* the most common penaeid species in the bay, was recorded in all samples, but its abundance decreased from November to March. Size ranged from 14.3 to 118.3 mm in males and from 12.7 to 133.6 mm in females, suggesting a slight sexual dimorphism related to body size. Males prevailed during most of the year; whereas, females predominated during summer and midwinter. Based on the percentage of mature females during this study, two main reproductive periods were identified, occurring in spring and autumn. Despite some breeding activity throughout the year, such a trend indicates that the population follows a tropical/subtropical reproductive pattern.

KEY WORDS: Population biology, Penaeidae, *Xiphopenaeus kroyeri,* reproduction, sex-ratio

INTRODUCTION

Xiphopenaeus kroyeri is the most intensively exploited shrimp species in São Paulo State. According to Pires (1992), *X. kroyeri* and the swimming crab *Portunus spinicarpus* (Stimpson 1871) are the most abundant species of the benthic megafauna in the continental shelf off the study area. This species represents the second most important fishery resource along the coast of São Paulo State (Rodrigues et al. 1993), and its trophic relationships may be essential in maintaining the stability of benthic communities (Pires 1992). Despite being an extremely abundant species along the Brazilian coast, information on the biology, ecology, and behavior of *X. kroyeri* is scarce (Vieira 1947, Mota-Alves and Rodrigues 1977, Cortés and Criales 1990, Cortés 1991, Rodrigues et al. 1993 and Branco et al. 1994).

Because of the complexity of their life cycle, studies on penaeid shrimp populations (e.g., migration and reproduction) are needed to improve fishery management. Boschi (1969) pointed out its importance when he studied *Artemesia longinaris* Bate 1888 in Mar del Plata, noting a continuous change of its age composition structure.

The study of penaeid reproductive cycles is also important, and usually is achieved by means of recording the degree of gonadal development in sampled specimens. In this procedure, a number of development levels are established and described, usually ranging from three to five (i.e., immature, in maturation, almost mature, mature, and spawned). Relevant contributions concerning the reproductive biology of different penaeid shrimp species are Vieira (1947), Olguin-Palácios (1967), Perez-Farfante (1969), Mota-Alves and Rodrigues (1977), Motta-Amado (1978), and El Hady et al. (1990). This study examines the abundance and the population biology of *X. kroyeri* in Ubatuba Bay, Ubatuba, São Paulo, Brazil, with emphasis on its population structure and reproductive period.

MATERIALS AND METHODS

Monthly trawlings were carried out from October 1992 to September 1993 in Ubatuba Bay. Samples were taken along two transects: transect A, located at the shallow midregion of the bay, and transect B located at the deeper bay mouth (Fig. 1). Trawlings were accomplished with an otter trawl net (10-mm mesh cod end) and were conducted at constant speed for 1 h, covering a 7,400 m^2 area. The shallow region of the bay is strongly affected by coastal environmental conditions, receiving freshwater drainage from four rivers. Otherwise, the deep stratum is to subject a greater oceanic influence.

Some physical factors were monitored at each transect. Bottom water temperature was obtained with a Nansen bottle provided with a thermometer (±1.0°C). Depth was obtained by means of a marked rope attached to the Nansen bottle, and a VanVeen grab sampler was used to obtain sediment samples. Sieving analysis according to Wentworth grades were carried out for grain size classification. Sediments were sorted using the phi-scale (ϕ) in 1.0-ϕ intervals between −1.0 ϕ and 4.0 ϕ, including the fractions under 4.0 ϕ (Hakanson and Jansson 1983). Sediment organic contents were obtained using the loss on ignition method (Hakanson and Jansson 1983).

The shrimps were separated, sexed, and measured (total length, TL) with a vernier caliper to the nearest 0.1 mm. A Student's *t*-test was used to detect size differences between sexes. Box plots were performed for males and females in each month to analyze the population structure through the study period. Monthly sex ratios were also obtained.

Median size differences between transects were tested in each month using a Mann–Whitney U-test and among months in each transect using a Kruskal–Wallis test (Síegel, 1956).

In each trawl, subsamples from 200 to 400 individuals were separated for examination of gonads. In females, four development stages were considered according to Motta-Amado (1978): I-immature, II-developing, III-mature, and IV-spent. In males, the presence (or absence) of spermatophores in the terminal ampoule was recorded.

Monthly sex ratios and proportions of mature females were statistically compared by means of a Goodman's test (1964, 1965).

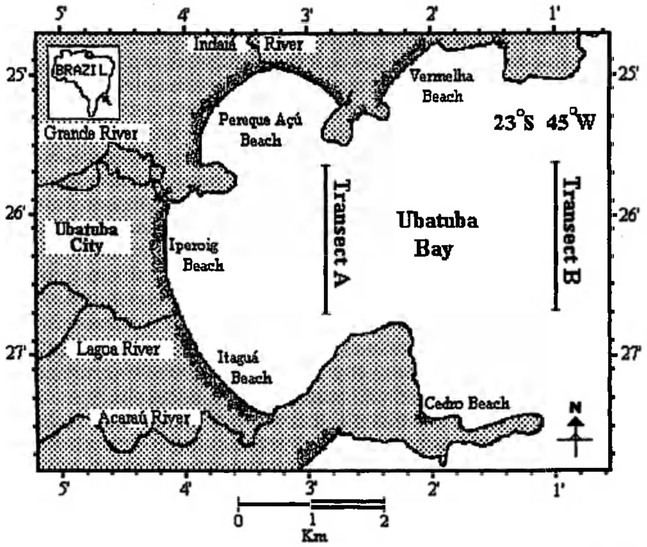

Figure 1. Map of Ubatuba Bay showing the position of sampling transects.

This analysis is based on the binomial proportion comparison for contrasts between and within multinomial populations. These results were analyzed at the 5% significance level.

To estimate the mean size of first maturation in each sex, the Galton's Ogive, $Fr = 1 - e^{-a \cdot TL^b}$ (Fonteles–Filho 1989), was adjusted to fit the total length (TL, independent variable) versus relative frequency of mature individuals (Fr, dependent variable) scatterplots. Mature individuals were defined as male with full terminal ampoule and females with gonads in stage II, III, or IV.

RESULTS

Water temperature averaged 23.16 ± 2.97°C (ranging from 20 to 28°C), with highest values recorded from February to April. Mean depth at transect A is 7.6 ± 1.3 m. Along this transect sediments are very poorly sorted ($\sigma_1 = +2.025$), mainly consisting of fine sand (Mz = 2.73 ϕ) with a high percentage of organic contents (11.66 ± 2.14%). Average depth at transect B is 14.6 ± 0.74 m. Sediments are moderately sorted ($\sigma = +0.525$), composed by very fine sand (Mz = 3.40 ϕ) and low organic contents (2.97 ± 0.61%).

Xiphopenaeus kroyeri was very abundant in the area (5,027 individuals in transect A and 5,282 in transect B) during all sampling periods, except from December to February in transect B (Fig. 2). This fact indicates a seasonal abundance variation.

Females ranged from 12.7 to 133.6 mm (74.52 ± 17.47) and

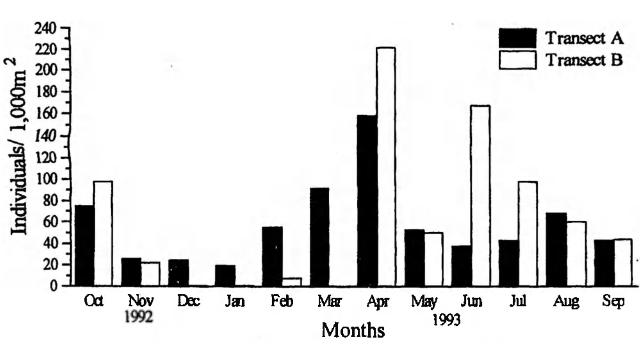

Figure 2. Monthly abundance of *X. kroyeri* in both transects.

males from 14.3 to 118.3 mm (71.82 ± 14.01), indicating a sexual dimorphism, in which females attain a larger size (Student's *t*-test, t = 8.825, p < .0001).

Mann–Whitney comparative analyses of size frequency distributions in transects A and B revealed significant size differences in Oct. 1992, Apr., May, June, and Aug. 1993 (Table 1, Figs. 3 and 4), showing that the population is not equally distributed in these areas. During Oct. 1992, April, and June 1993, larger shrimps were sampled in transect A, and during May and Aug. 1993, larger specimens were captured in transect B.

Differences in shrimp median size were repeatedly verified among sampled months (Kruskal–Wallis, p < .001) (Table 2, Figs. 3 and 4). However, they were too complex to reveal recruitment pattern.

Males were generally slightly predominant, but the sex ratio varied throughout the year. In November 1992, January and July 1993 (Fig. 5), an increase (Goodman's test, p < .05) of the relative number of females was observed, when sex ratios attained 1:1.78; 1:1.28, and 1:1.2, respectively.

Xiphopenaeus kroyeri breeds all year, but higher reproductive activity was verified in some periods. Based upon the data obtained from gonadal analysis in females, it can be concluded that higher reproductive activity occurred in November 1992, and March, August, and September 1993 (Fig. 6). In the case of males, higher proportions of individuals with full terminal ampoule were recorded in two main periods (November 1992 and May 1993) (Fig. 7). Males achieve sexual maturity (68.02 mm) at a smaller size than females (83.19 mm) (Fig. 8).

DISCUSSION

The abundance of *X. kroyeri* showed a marked seasonal variation. During the summer period (December to March) this species' abundance is lower, mainly in the deeper portion of the bay. Signoret (1974) observed that *X. kroyeri* follows a similar pattern in the Terminos Lagoon (México), with low abundances from summer to fall.

The low abundance of *X. kroyeri* during summer may be related to the intrusion of a cold current. Castro-Filho et al. (1987) indicated the presence of three oceanic currents in the Ubatuba region, the coastal water (CW) (T > 20°C), the South Atlantic central water (SACW) (T < 18°C), and the tropical water (TW) (T > 20°C). Pires (1992), who studied the benthic megafauna communities in the continental shelf of Ubatuba region, observed by means of a cluster analysis that there is a close association between some species abundance and specific environmental conditions. This is the case of positive correlation between *X. kroyeri* and the prevalence of CW during winter.

Despite different sediment features found in each transect, the incoming SACW during summer could be the most important physical factor influencing the distribution of this species. The physical action of the current itself together with low temperature conditions would restrain the population distribution of *X. kroyeri* within the study area.

Statistical differences in shrimp median size among sampled months do not support a growth model through time, which could have explained the growth pattern in this population. The great fishery effort in Ubatuba Bay probably affects the species, as observed by Somers et al. (1987) in *P. esculentus* Haswell in the Torres Strait (Australia), who suggested a continuous recruitment and/or the existence of a size-dependent source of mortality. In the present study, the comparison of shrimp size in transects A and B,

TABLE 1.

Mann–Whitney analysis in *X. kroyeri* size comparisons in each month between transects in Ubatuba Bay.

	Transect A		Transect B		
Month	Number of individuals	Ranked sums	Number of individuals	Ranked sums	U
October 1992	552	735.56	719	559.57	8.47*
November 1992	193	180.08	163	176.63	0.31
December 1992	184	95.00	7	122.28	1.28
January 1993	142	73.79	4	63.25	0.50
February 1993	409	229.59	52	242.08	0.63
March 1993	673	—	0	—	—
April 1993	1169	1568.07	1640	1288.34	8.996*
May 1993	390	351.24	370	411.34	3.77*
June 1993	275	816.52	1235	741.91	2.56*
July 1993	281	509.77	695	479.90	1.50
August 1993	466	381.11	401	495.46	6.70*
September 1993	293	296.16	296	293.85	0.16

* Statistical significant differences at $\alpha = 0.01$.

reveals remarkable differences in the population distribution, which are likely to reflect recruitment and migration processes.

The sex ratio variations observed in this study are supported by other results obtained for the same species. According to Signoret (1974), the sexual distribution through the year in *X. kroyeri* is not homogeneous, with males and females often strongly segregated.

According to Wenner (1972), mentioning the Fisher theory, the 1:1 proportion is favored by natural selection. Wenner (1972)

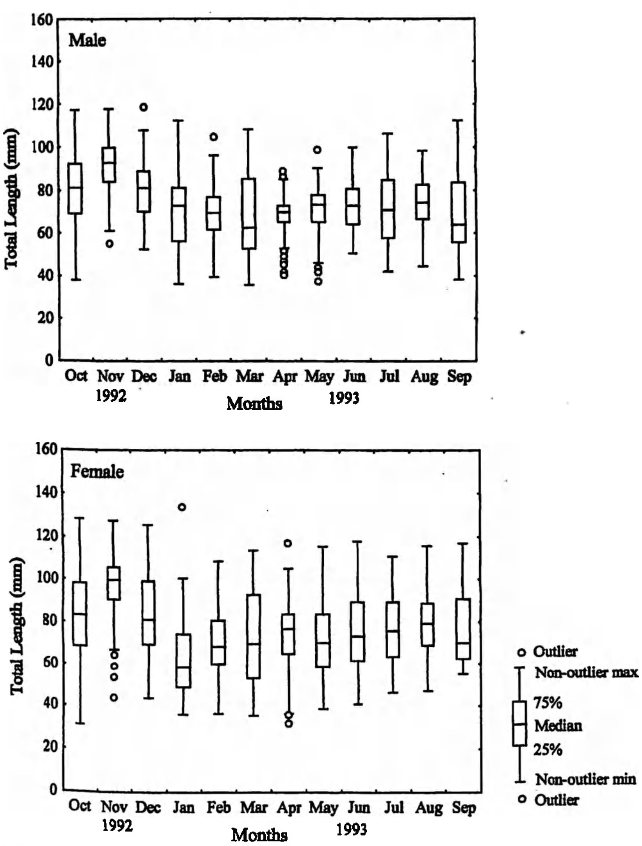

Figure 3. Series of box plot graphics for monthly size of males (upper) and females (below) obtained in transect A.

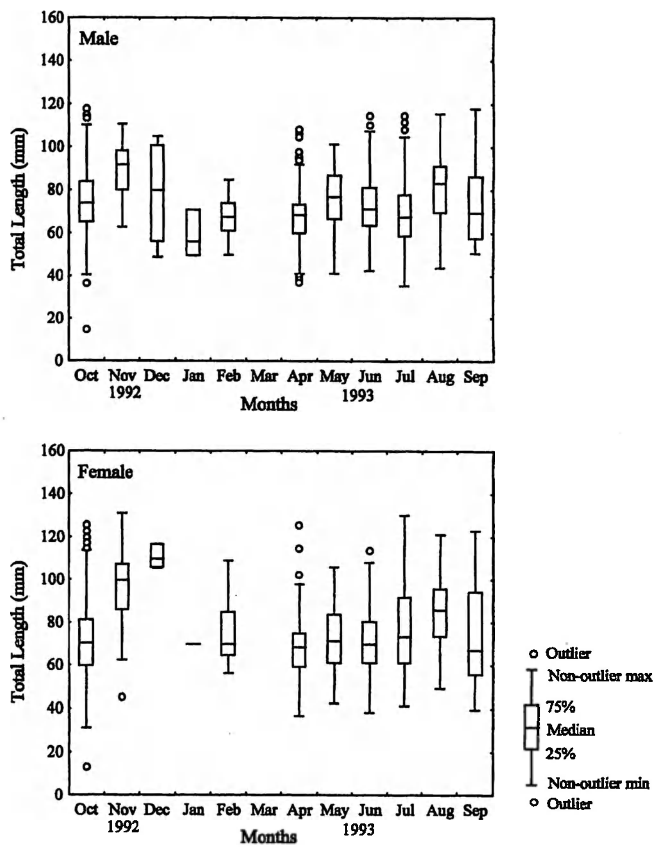

Figure 4. Series of box plot graphics for monthly size of males (upper) and females (below) obtained in transect B.

TABLE 2.

Results of Kruskal–Wallis analysis.

Transect	n	H	df	Probability
A	5027	576.25	11	$p < .001$
B	5282	640.68	10	$p < .001$

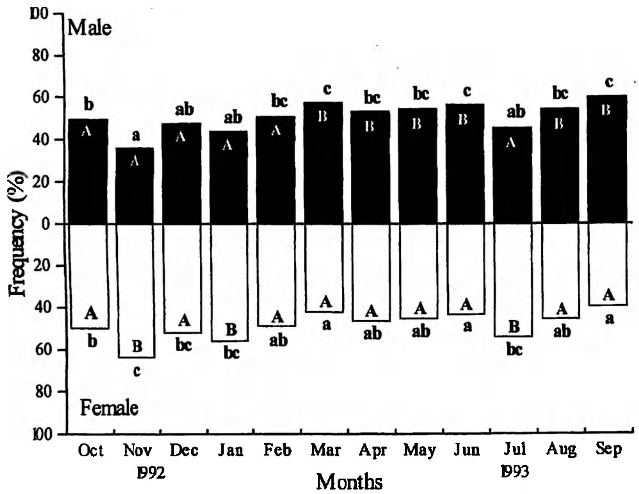

Figure 5. Monthly sex ratio for *X. kroyeri*. Capital letters inside the bars indicate comparisons within month, and lower case letters outside the bars indicate comparisons among months. The same letters indicate no statistical differences.

pointed out that sex-dependent mortality, activity, migration, habitat utilization and also the effect of restricted food resources are important factors explaining departures from the Mendelian proportion. Wenner also stated that the 1:1 ratio is an exception rather than the rule in crustacean populations. He concluded that sex ratio can be a function of size for a given species.

The temporal sex ratio variation can be related to a seasonal reproductive pattern in *X. kroyeri*. The proportion of males was higher during most of the year, but females were more abundant in November (spring), when it was recorded a 1:1.78 sex ratio. This peak coincides with major reproductive activity. Contrarily, Cortés (1991) observed that during spawning, males outnumbered females in a Colombian Caribbean population. This fact supports the hypothesis of sex-dependent pattern of migration, because Cortés collected the shrimps near the coast at depths ranging from 1.5 to 3 m.

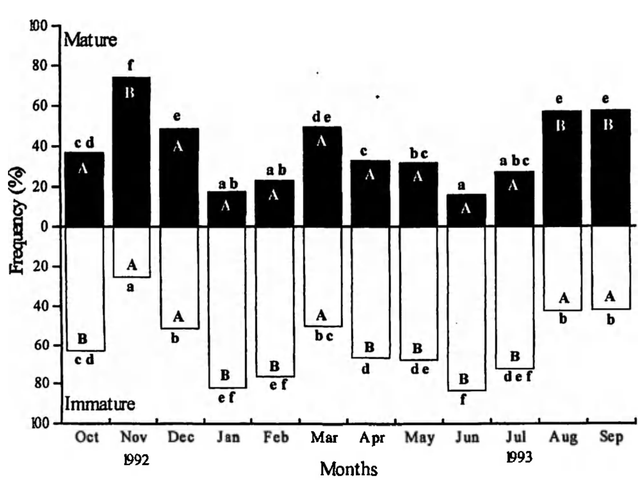

Figure 6. Bar graph showing gonadal maturity in females. Capital letters inside the bars indicate comparisons within month, and the lower case letters outside the bars indicate comparisons among months. The same letters indicate no statistical differences. Data of transects A and B are grouped. Females in gonad stage I were considered immature, and females in stages II, III, and IV were considered mature.

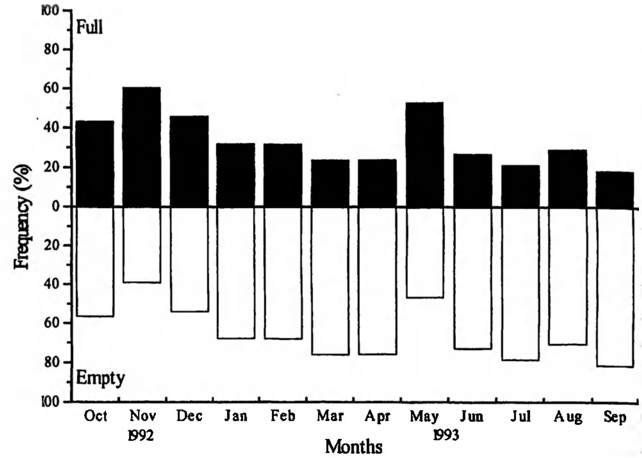

Figure 7. Terminal ampoule status in males.

Analyzing both transects, we can assume that *X. kroyeri* exhibits a tropical/subtropical reproductive pattern (Dall et al. 1990), in which there is a main reproductive period in the spring and a secondary one in the fall. The present results are similar to those observed by Mota-Alves and Rodrigues (1977), Motta-Amado (1978), and Cortés (1991). It can be assumed that the presence of juvenile individuals from February to May is attributable to spawning events during spring.

The onset of sexual maturity can vary between populations. The size estimates in this study (68.02 mm in males and 83.19 mm in females) are larger than those observed by Rodrigues et al. (1993) (62 mm for males and 71 mm for females) in other localities within São Paulo State. The determination of this parameter can be important for assessment of the reproductive stock in natural populations (Fonteles-Filho 1989) and for guidance of future governmental fishery control. Establishing a minimum catch size and defining the period of lower relative abundance of juvenile shrimps will help establish rational management of this species exploitation.

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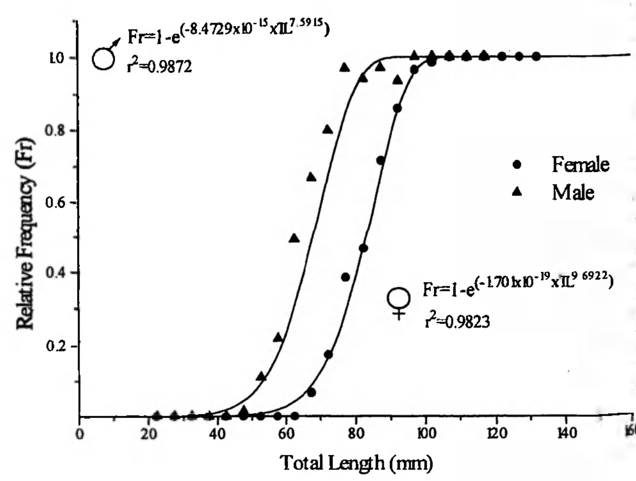

Figure 8. *X. kroyeri*. Frequency of morphologically mature males and females as a function of total length.

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