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Diel variation in abundance and size of the seabob shrimp *Xiphopenaeus kroyeri* (Crustacea, Penaeoidea) in the Ubatuba region, Southeastern Brazil

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ABSTRACT

The objective of the present study was to analyze diel variation in the abundance and size of the seabob shrim *Xiphopenaeus kroyeri* in the Ubatuba region, state of São Paulo, during the year 2000. In each season of the ye collections were made in the day and at night on 9 transects at depths ranging from 2 to 40 m. The estimated shrim amount was of 28,878 individuals. Although the catch rate was higher during the day (15,853 shrimp), this did n differ significantly from the catch at night (13,025). The catch rate was higher in daytime on most transects, but w higher at night at locations where fine and very fine sand predominated. The majority of juveniles were caught duri the day. The mean size (CL) was 14.43 ± 4.02 mm for day and 14.82 ± 4.28 mm for night samples, and the differen was significant (Student's t-test, $df = 2, 429$, $t = 2.27$, $p = 0.02$). The largest individuals were caught during the nig None of the three models that have been proposed in the literature to account for differences in the diurnal catch patte of penaeid species can be applied to *X. kroyeri*. Our results provide evidence that sediment type not only influenc the catch rate in the analyzed periods, but also determined which models might fit the behavior of this species.

Key words: abundance, distribution, Penaeidae, *Xiphopenaeus kroyeri*.

INTRODUCTION

The tropical marine shrimp fishery, mainly for penaeid shrimps, is a very old activity. In recent decades, the mechanization of fishing boats and the growth of shrimp fleets have intensified exploitation, which has caused declines and even collapse of these fisheries. In Brazil, with the significant decline of the shrimp *Farfantepenaeus* spp. since the 1980s (Paiva 1997), the population of *X. kroyeri*, commonly called as "sete-barbas", became cause of continuous indiscriminate harvesting, cially in the state of São Paulo (Costa et al. 2007

Sediment type and depth have been emphas major variables affecting the distribution of the p shrimps (Dall et al. 1990). Several studies have d strated the substrate influence on some shrimp bio processes, since shrimps live on the substrate or bu it (Fuss Jr and Ogren 1966). The majority of spe mains buried during the day and emerge at dusk,

Negreiros-Fransozo et al. 1999). Moctezuma and Blake (1981) noted that juveniles remain unburied for a longer period than adults do, because they need more food as a result of their high growth rate. In addition, Penn (1984) noted that the type of substrat can affect burying behavior: in locations with silt and clay sediments, the turbidity of the water may be higher, and here the catch does not differ among the periods. In sandy locations, turbidity is lower and the shrimps are more abundant at night.

Xiphopenaeus kroyeri (Heller, 1862) is widely distributed in the western Atlantic (Virginia, USA, to Rio Grande do Sul, Brazil) and the eastern Pacific (Mexico to Peru) (Pérez-Farfante and Kensley 1997). However, recently, Gusmão et al. (2006) demonstrated through molecular data that *X. kroyeri* is distributed only in the Atlantic, while *Xiphopenaeus riveti* occurs in the Pacific. *X. kroyeri* is the second most important fishery resource in abundance in the Southeastern Brazil, and is the most heavily exploited benthic shrimp species on the coast of the state of São Paulo (D'Incao et al. 2002, Castro et al. 2005).

Most studies on *X. kroyeri* have been focused on their abundance and ecological distribution (Fransozo et al. 2002, Costa et al. 2007, Castilho et al. 2008), population structure, and reproductive biology (Nakagaki and Negreiros-Fransozo 1998, Fransozo et al. 2000, Castro et al. 2005). Studies of the variation in catch and size of the seabob shrimp during the day and night periods are practically nonexistent. The only study of this nature was carried out by Negreiros-Fransozo et al. (1999), in the same region as the present study, for the species of Penaeoidea, although it had been carried out in only two seasons of the year (summer and winter) and at mean depths of 3.5 ± 0.5 m. These authors found that the number of individuals of these species did not differ among the analyzed periods, although larger shrimps were more often found at dusk. At this location, silt and clay predominate (Costa et al. 2007). Although this previous study had been carried through in depths until 3.5 m, one knows that in Ubatuba, which is in the north coast of the state of São Paulo, *X. kroyeri* was distributed preferentially down to a depth of 25 m (Costa posal of Penn (1984), these factors can modify the catch pattern of a penaeid shrimp.

Thus, the objective of the present study was to analyze the diel variation in abundance and size of individuals of *X. kroyeri* that were caught down to a depth of 40 m in the Ubatuba region, on the northern coast of the state of São Paulo. We also investigated whether a change in sediment type might alter the catch rate between the day and night periods. The present study also provided information on the periods and regions that juveniles are more vulnerable to the fishing, therefore serving as framework for the determination and implantation of management plans that propitiate a sustainable fishing.

MATERIALS AND METHODS

Located along the northern coastline of the state of São Paulo, the Ubatuba region is an important area for crustacean research (Mantelatto and Fransozo 2000). The region is unique when compared to other areas along the Brazilian southern coast. This coastal area is enclosed be within a system of inlets, bays, canals, bayous, and rivers bordered by mangroves that together form estuaries rich in nutrients that are favorable for the establishment and development of the marine fauna. In addition, Ubatuba Bay is fairly pristine and used as a standard for comparison with other marine habitats that are strongly influenced by humans (Mantelatto and Fransozo 1999).

The collections were carried out in all four seasons of the year (summer, autumn, winter and spring) in day and night periods, in the Ubatuba region (Fig. 1), during the year 2000. The samples were taken along 9 bottom transects, at depths of 2, 5, 10, 15, 20, 25, 30, 35 and 40 m. We used a commercial fishing boat equipped with two Mexican-type "double rig" nets. The mesh size of the nets was 20 mm knot-to-knot in the body, and 15 mm in the cod end. Trawls were conducted along each transect for 30 minutes, over a distance of approximately 2 kilometers. Specifics nets for the capture of the shrimp-white were used to prevent the capture of the animals buried in the substratum, i.e., with lighter materials and a high number of floats. The boat speed was also changed

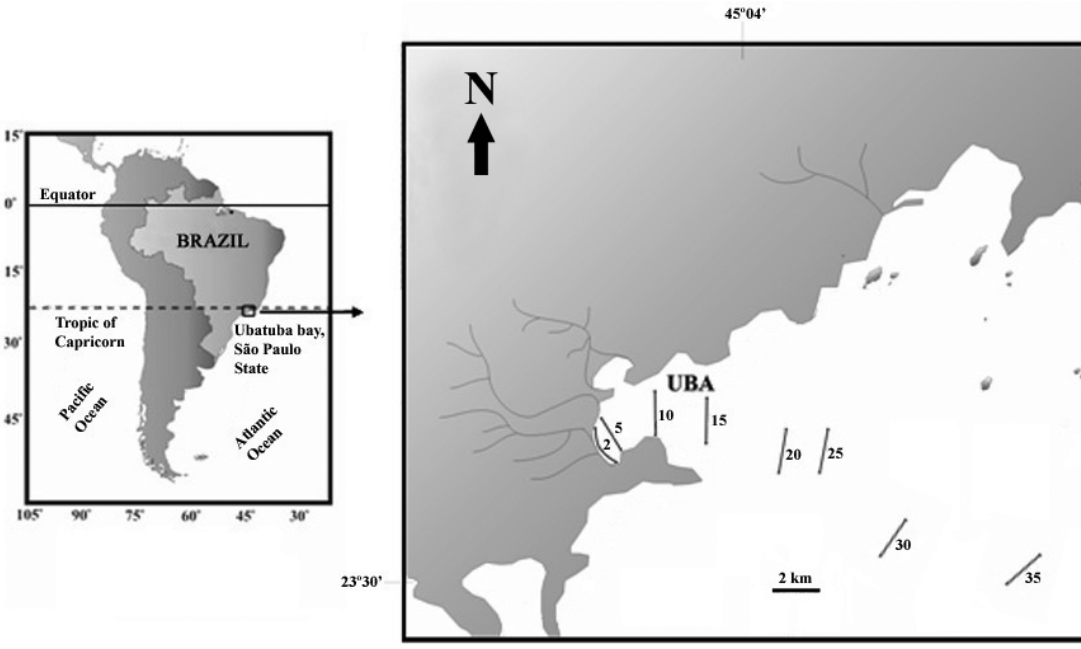


Fig. 1 – Map of the Ubatuba (UBA) region.

dom 250-g subsample, and the number of individuals was counted on each transect of each season. Based on the data from the subsample and from the total biomass, it was possible to estimate the number of individuals for each transect, season, and period.

All the individuals in the subsample were measured for carapace length (CL mm) in millimeters and were sexed. Carapace length, means the distance from the orbital angle to the posterior margin of the carapace. The reproductive condition of the females was determined by the macroscopic observation of the gonads, adapted from Bauer and Lin (1994) and Costa and Fransozo (2004), with four stages of development: IM = immature, RU = rudimentary (adults with undeveloped gonads), ED = developing, and DE = developed. The reproductive status of males was assessed by examining the shape of the petasma, which is fused in adult individuals (Castro et al. 2005).

The sediment was measured on each transect of each season. Details of the methodology are found in Bertini et al. (2001). The abundance of shrimp was com-

isons test, at the 5% probability level. For eac
sect and season, the chi-square test (X^2) was u
compare the abundance of juveniles and adults b
the sampled periods (day and night). The carapa
of individuals in each season and on each transe
compared between the day and night periods, by
of Student's *t*-test. Data were log-transformed p
the analysis, to improve their normality (Zar 199

RESULTS

The highest mean values of sediment diameter (
were found in the transects of 5 to 15-m depth
seasons (Table I).

The estimated shrimp amount was of 28,87
viduals: 22,993 (80%) in winter, 3,042 (11%) in su
2,562 (8%) in autumn, and only 281 (1%) in sprin
largest number of specimens (24,678) was obtai
the 2 and 10-m transects; a total of 4,200 indi
were found on the 15 to 25-m transects. No shrim
collected on the 30, 35 or 40-m transects. The nu

TABLE I
The mean diameter of the sediment (phi) at each transect during the seasons in the year 2000.

	phi (Φ)				
Transects	Summer	Autumn	Winter	Spring	Mean ± SD
2m	5.93	3.48	5.98	5.93	5.33 ± 1.06
5m	5.93	5.93	5.93	5.93	5.93 ± 0.00
10m	6.18	6.18	6.18	6.18	6.18 ± 0.00
15m	5.73	5.73	5.73	5.73	5.73 ± 0.00
20m	4.28	4.28	4.28	4.28	4.28 ± 0.00
25m	2.72	2.94	4.31	2.91	3.22 ± 0.63
30m	3.08	3.08	2.74	2.94	2.96 ± 0.13
35m	2.98	0.07	3.22	2.59	2.21 ± 1.25
40m	4.19	4.02	4.18	2.27	3.66 ± 0.80

SD = standard deviation.

TABLE II
Numbers of individuals of *Xiphopenaeus kroyeri* collected in different periods (day and night) on the transects from 2 to 25 m depth and in the four seasons of the year. The results of Tukey's test are indicated by letters: the same letter indicates that the results did not differ significantly.

Transect	Tukey	Period	Summer	Autumn	Winter	Spring	Total
2m	A	D	948	1,017	4,933	5	**6,903**
		N	1,072	235	4,310	15	**5,632**
5m	A	D	383	83	5,508	56	**6,030**
		N	602	456	3,674	115	**4,847**
10m	A,C	D	0	380	421	15	**816**
		N	37	265	74	74	**450**
15m	B,C	D	0	82	1,938	0	**2,020**
		N	0	0	1,970	1	**1,971**
20m	B	D	0	0	0	0	**0**
		N	0	12	93	0	**105**
25m	B,C	D	0	23	61	0	**84**
		N	0	9	11	0	**20**
Total	—	**D**	**1,331**	**1,585**	**12,861**	**76**	**15,853**
		N	**1,711**	**977**	**10,132**	**205**	**13,025**

*significant at <0,05.

Overall, in spite of the higher catch rate during the day (15,853 shrimp), there was a significant difference from the night samples (13,025) (X^2 p = 3.48 E-62). The number of individuals increased at night in spring (205 ind. at night and 76 ind. in daytime – X^2: p = 1.40 E-14) and in summer (1,711 ind. at night and 1,331 ind. 3.07 E-33); and in winter, 10,132 shrimps were caught at night, and 12,861 in daytime (X^2, p = 2.04 E-72) (Fig. 2).

The number of individuals differed significantly on most transects (X^2 (1-m) p = 7.22 E-30; (5-m) p = 8.02 E-30; (10-m) p = 8.11 E-25; (20-m) p = 1.22 E-24;

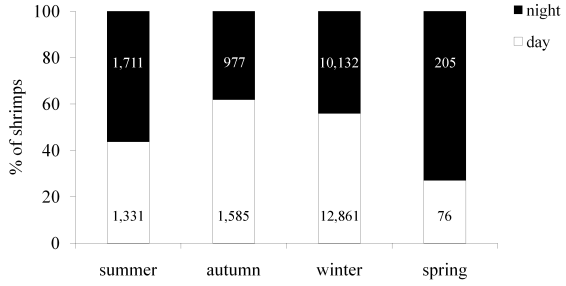


Fig. 2 – Percent variations of individuals of *Xiphopenaeus kroyeri* collected in the day and night periods, by season (summer, autumn, winter and spring). Numbers of individuals are inside of the bars.

(phi >4). In contrast, at the 20-m depth, shrimps were caught only at night. At this point, the values of (phi) decreased to close to 3, that is, very fine sand predominated (Fig. 3). The same pattern was observed for juveniles, although the catches at the 10 (X^2, p = 0.001), 15 (X^2, p = 0.02) and 20-m (X^2, p = 0.07 E-10) depths differed significantly (Fig. 4).

The overall mean size (CL) of individuals was 14.43 mm in day samples and 14.82 mm in night samples, which is a significant difference (Student's *t*-test, df = 2429, t = 2.27, p = 0.02). The largest individuals, including all those with a carapace length above 28 mm, were caught at night (Fig. 5).

Comparing the seasons of the year, the mean size of the individuals was larger in night samples, but a statistical difference was apparent only in autumn (Student's *t*-test, df = 541, t = 2.08, p = 0.03) (Fig. 6). In terms of spatial relationships, except for the 15-m depth, the mean carapace size of adults collected at night was larger than the carapace size found in the day samples. The largest individuals were collected at the deeper localities, 15 and 20 m (Fig. 7).

DISCUSSION

The catch rate of individuals of *X. kroyeri* was slightly higher in daytime. This result contrasts with the majority of studies on marine shrimps, mainly of the superfamily Penaeoidea (see, Fuss Jr and Ogren 1966, Pérez-Farfante 1971, Cobb et al. 1973, Bauer 1985, Scelzo 2003). In the same region of this study, Lopes et al.

Diurnal burying activity is common in the m
of penaeids (Bishop et al. 2008). The burrowing
ior of penaeids is a strategy for energy conserva
well as a means of defense against potential pr
(Kutty and Murugopoopathy 1968, Dall et al.
Shrimps that bury themselves in the substrate dur
day are protected against predators that feed in t
riod, and are less active than those that do not bu

Penn (1984) developed three models for b
behavior, based on studies with penaeids caught
Gulf of Mexico: Type 1 – Strongly nocturnal,
ten inactive or buried at night, although always
during the day. The species included here are ge
fished for in sandy substrates with relatively clear
Type 2 – Generally nocturnal and continually a
night, and buried during the day but with a tend
emerge occasionally. These species differ from
in being generally associated with muddier sub
Such areas generally have more turbid water; Ty
Rarely bury themselves and almost continually
These are almost exclusively found in areas of riv
charge, which are characterized by high turbidity

For *Xiphopenaeus kroyeri*, it is difficult to p
a single pattern in conformity with these three m
Our results showed that, the sediment type of th
area, the size of individuals also affected the cat
tern. At 20 m depth, the shrimps were only fo
night, the individuals presented largest sizes, and t
iment was composed of sand and, consequently,
depth, the shrimps would be considered of the T
In contrast, for the shallower depths, the Type 3
could be proposed because there was no great m
cal change in catch rate between day and night. S
clay predominated at those locations, suggesting t
water there may be more turbid. In this respec
the juveniles and adults of *X. kroyeri* showed th
behavior.

Laboratory experiments with *X. kroyeri* co
rate our proposal, since the shrimps buried them
during the day and emerged at night in sediment
posed of fine and very fine sand. When the shrimp
placed on muddy substrates, they began to burro

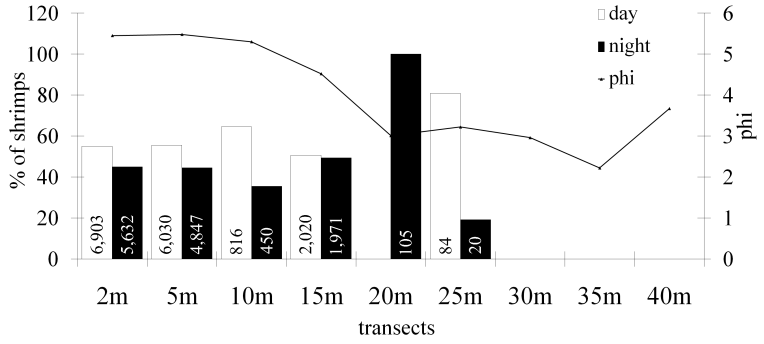


Fig. 3 – Values of phi and percent variations of individuals of *Xiphopenaeus kroyeri* collected in the day and night periods, by transect. Numbers of individuals are inside of the bars.

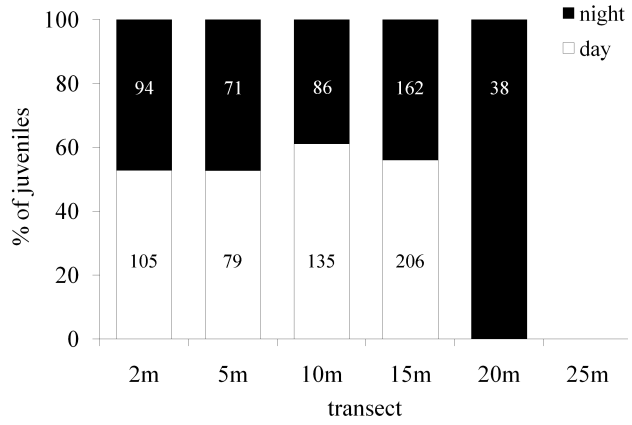
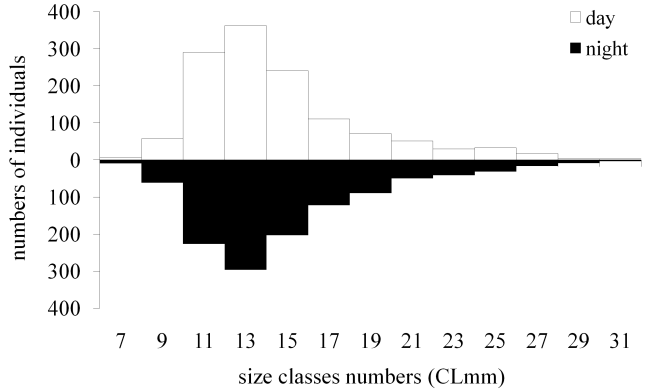


Fig. 4 – Percent variations of juveniles of *Xiphopenaeus kroyeri* collected in the day and night periods, by transect. Numbers of individuals are inside of the bars.



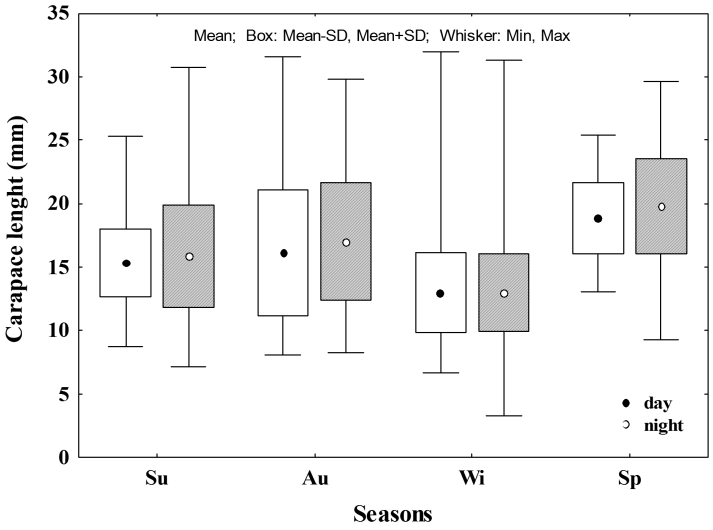


Fig. 6 – Means of sizes of individuals of *Xiphopenaeus kroyeri* (CL, mm) in the day and night periods, by season. Su = summer, Au = autumn, Wi = winter and Sp = spring.

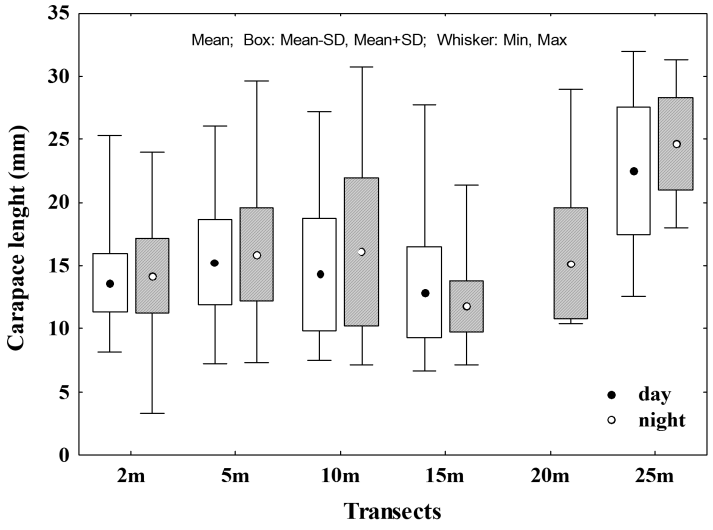


Fig. 7 – Means of size of individuals of *Xiphopenaeus kroyeri* (CL, mm) in the day and night periods, by transect. Asterisk indicates a significant difference (Student's *t*-test) between sampling periods.

hole that they had dug (F.A.M. Freire et al., unpublished data). According to Penn (1984), other penaeid species

are not capable of reversing the water flux that through their branchial chamber in order to avoi

The suspension of the substratum is caused many times because the wind action (Pedersen et al. 1995) and, consequently, increasing the turbidity of the water. In accordance with Castro-Filho et al. (1987), the strongest winds in the winter induces the penetration of Tropical Water straight to the direction to the coast, destroying the seasonal thermocline formed by the action of the South Atlantic Central Water and directing these masses to the continental slope. Although we did not analyze the wind action in the present study, this fact could have favored the increase of the water turbidity in the autumn and winter months and, consequently, allowing the increase of the individuals captured during the day.

With respect to size, our results agree with the findings of Negreiros-Fransozo et al. (1999), who collected the largest individuals at dusk. According to Dall et al. (1990), juvenile penaeid shrimps do not show a strong response of burying behavior in relation to light as the adults do, which are more caught during the night. In part, this hypothesis can be supported here, in that the smaller individuals of *X. kroyeri* were caught in about the same numbers in both periods, and the larger individuals were collected more often during the night. However, the adults, even smaller-sized ones, when in shallower areas, showed the same behavior as the juveniles. Experimental studies involving these demographic classes in different types of sediment between the day and night periods might elucidate this question.

The abundance of juveniles and adults varies seasonally in the study region (Costa et al. 2007), mainly due to the changes of the monthly temperatures values. The present study corroborates the results above. Moreover, beyond autumn and winter present values of bottom temperatures higher than spring and summer ones (Costa et al. 2007), we also suggest that the highest number of individuals in this period could be the result of the off-season period (March to May) for all the shrimps. In this way, the unification of the closure period as presently proposed for the pink and seabob shrimps is supported by this study.

In general, we can conclude that, for *X. kroyeri*, the sediment type is the main factor that affects the catch rate adult males, and ripe and spent females) in relation to lunar phases and the tidal cycle may contribute to a greater understanding of its behavior.

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RESUMO

O objetivo do presente estudo foi analisar a variação diuturna na abundância e no tamanho do camarão sete-barbas *Xiphopenaeus kroyeri* na região de Ubatuba/São Paulo, durante o ano 2000. Em cada estação do ano, as coletas foram realizadas no período diurno e noturno, em 9 transectos localizados nas profundidades de 2 a 40 m. Um total de 28.878 camarões foi obtido e apesar da maior taxa de captura observada durante o dia (15.853 camarões), não houve diferença significativa em relação ao período noturno (13.025). Na maioria dos transectos houve também uma maior taxa de captura de camarões durante o dia, no entanto, verificou-se que em locais com sedimentos com predominância de areia fina e muito fina, houve uma captura no período noturno. Já em relação aos juvenis, a maioria dos indivíduos foi amostrada durante o dia. Em consideração ao tamanho (CC) médio, obteve-se o valor de 14,43 $\pm$ 4,02 mm durante o dia e 14,82 $\pm$ 4,28 mm durante a noite, com significativa diferença (Student's t-test, df $=$ 2.429, t $=$ 2,27, p $=$ 0,02). Verificou-se também que os maiores indivíduos foram capturados no período noturno. Um único modelo dos três propostos na literatura para as espécies de peneídeos quanto ao padrão de captura diuturna não pode ser aplicado ao *X. kroyeri*. Nossos resultados evidenciaram que tipo de sedimento não somente influenciou na taxa de captura entre os períodos analisados como determinou os modelos em que esta

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