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SEX RATIO AND SEASONAL ABUNDANCE OF SEABOB SHRIMP Xiphopenaeus kroyeri *lato sensu* (DECAPODA: PENAEIDAE) IN THE NORTHEASTERN BRAZILIAN COASTAL ECOREGION

Razão sexual e abundância sazonal do camarão sete-barbas *Xiphopenaeus kroyeri* lato sensu (Decapoda: Penaeidae) na ecorregião costeira do nordeste brasileiro

Valeria Maria Melo-Lima[1], Igor Da Mata-Oliveira[2], Flavia L. Frédou[3], Petrônio A. Coelho *(in memorian)*, Petrônio A. Coelho-Filho[4]

[1]Instituto de Desenvolvimento Rural do Tocantins – RURALTINS. Quadra 302 Norte, Av. NS, lotes 01, 02 - PD Norte, Palmas – Tocantins, Brasil. Cep: 77006-340.
[2]Laboratório de Investigação e Manejo da Pesca, Universidade Federal de Alagoas, Campus Arapiraca, Unidade Penedo, Av. Beira Rio, s/n, Centro Histórico, Penedo – Alagoas, Brasil. CEP: 57200-000.
[3]Laboratório de Avaliação dos Impactos Antrópicos na Zona Costeira e Marinha (Biompact), Departamento de Pesca e Aquicultura, Universidade Federal Rural de Pernambuco. Rua Dom Manuel de Medeiros, s/n, Dois Irmãos, Recife - Pernambuco, Brasil. CEP: 52171-900.
[4]Laboratório de Carcinologia, Universidade Federal de Alagoas, Unidade Penedo. Av. Beira Rio, s/n, Centro Histórico, Penedo - Alagoas, Brasil. CEP: 57200-000. E-mail: petronio.filho@penedo.ufal.br

ABSTRACT

This study evaluated the sex ratio and seasonal abundance of the seabob shrimp Xiphopenaeus kroyeri *at the mouth of the São Francisco River, Northeastern Brazil, from 2008 to 2009. A total of 3,072 individuals were collected, measured for carapace length (in mm), and classified by sex and developmental stage. Shrimps were categorized according to the capture period (dry or rainy season). Size distribution ranged from 8-34 mm, with the highest concentration in the 18-20 mm class. Females were significantly more abundant and larger, predominating in most size classes. Juveniles represented 3.5% of the specimens, being more frequent in the dry season. There was no difference in adult participation between the analyzed periods. The dominance of females may be influenced by fishing selectivity, which tends to capture larger individuals. This study provides insights for the sustainable management of* X. kroyeri *stocks, highlighting the importance of management measures to maintain population viability, especially in the face of overfishing of reproductive stocks.*

Keywords*: Penaeid, sexual dimorphism, length classes, seasonality, Population dynamics.*

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RESUMO

Este estudo avaliou a razão sexual e a abundância sazonal do camarão sete-barbas *Xiphopenaeus kroyeri* na foz do Rio São Francisco, Nordeste do Brasil, entre 2008 e 2009. Foram coletados 3.072 indivíduos, medidos em comprimento da carapaça (em mm) e classificados por sexo e estágio de desenvolvimento. Os camarões foram categorizados conforme o período de captura (seco ou chuvoso). A distribuição de tamanho variou entre 8-34 mm, com maior concentração na classe de 18-20 mm. Fêmeas foram significativamente mais abundantes e maiores, predominando na maioria das classes de tamanho. Juvenis representaram 3,5% dos espécimes, sendo mais frequentes no período seco. Não houve diferença na participação dos adultos entre os períodos analisados. A dominância de fêmeas pode ser influenciada pela seletividade da pesca, que tende a capturar indivíduos maiores. Este estudo fornece subsídios para a gestão sustentável do estoque de *X. kroyeri*, ressaltando a importância de medidas de manejo para manter a viabilidade das populações, especialmente em face da sobrepesca dos estoques reprodutivos.

Palavras-chave: Peneídeo, dimorfismo sexual, classes de comprimento, sazonalidade, dinâmica populacional.

INTRODUCTION

Marine shrimp are among the most important internationally traded fishing resources, due to their high appreciation, acceptance and high market value worldwide, ranking among the top ten most caught penaeid shrimp globally (FAO, 2014). The productive chain generated from its production is wide and diverse, encompassing industrial and artisanal trawler fleets, thousands of fishermen, and jobs in processing and marketing (Gillet, 2008; FAO, 2018).

The commercial exploitation of coastal penaeid shrimp in the intertropical zone is a traditional activity, with a fundamental social and economic importance, especially for many developing countries, being source of income generation of several fishing communities around the world (Gillet, 2008; FAO, 2018). The shrimp fishing in these areas, even being predominantly artisanal, is carried out by motorized boats with bottom trawls, being a predatory and destabilizing activity that modifies the structure and the dynamics of benthic populations (Sedrez *et al*., 2013; Silva Júnior *et al*., 2015; Pham *et al*., 2019).

In Brazilians tropical water, the pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817) and *F. subtilis* (Pérez-Farfante, 1967), the seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) and the white shrimp *Litopenaeus schmitti* (Burkenroad, 1936), and) and are the target species of the shrimp fishing. Among these, *X. kroyeri* (lato sensu) stands out for the volumes landed, being one of the top ten most caught penaeid shrimps in the world (FAO, 2014). This fact is explained by it widely distribution, from Rio Grande do Sul – Brazil (32° 39′S and 52° 20′W) to Virginia – USA (36° 54′N and 75° 43′W) (Costa *et al*., 2007), and great in areas near estuaries mouth up to 30 m depth constituting a dominant epifaunal organism, making it an accessible resource for small scale coastal fisheries (Santos & Silva, 2008; Dias-Neto, 2011; Thomé-Souza *et al*., 2014).

Recently, multigenic and morphological studies have expanded the diversity of shrimp *Xiphopenaeus*, with the description of two new species of the genre on the Brazilian coast (Carvalho-Batista *et al*., 2019). As the collections of the present work were performed before the study, some of the specimens analyzed may not be *X. kroyeri stricto sensu*. Therefore, we use the denomination "*lato sensu*" when referring to the classification of the species in the present study.

Brazil is historically the major *X. kroyeri* producer in where represents 26,94% of all marine crustaceans' landings (MPA, 2011). The largest volume of catches of *X. kroyeri* is concentrated in the states of Bahia, Maranhão and Alagoas (IBAMA, 2007) located in the Northeastern Brazil Marine Ecoregion (Salding *et al*., 2007). In this last one, the mouth of the São Francisco River, between Alagoas and Sergipe, is the most important shrimp fishing area, accounting for approximately 20% of the region's catches (Thomé-Souza *et al*., 2014). The species is also the most captured fishing volumes on the coast of São Paulo state (Ávila-da-Silva *et al*., 2018, 2019).

Due to its economic importance throughout its area of occurrence, *X. kroyeri* has been the subject of several studies in Brazil (Graça-Lopes *et al*., 2007; Pezzuto *et al*., 2008; Lopes *et al*., 2010, 2014; Heckler *et al*., 2013a; Heckler *et al*., 2013b; Castilho *et al*., 2015). Although, given the wide latitudinal range in which *X. kroyeri* occurs, associated with a variety of environmental conditions, these findings may not be applicable to all populations of the species. Indeed, biological and morphological parameters, reproductive periods and spatio-temporal distribution of *X. kroyeri* differ between the regions studied (Fernandes *et al*., 2011; Heckler *et al*., 2013a).

The study of sex ratio of natural populations is considered basic information, as it provides subsidies to the knowledge of their populational stability (Lopes *et al*., 2010), as they may present changes in their structure and behavior resulting from increases in the levels of exploitation. In this sense, this study analyzes the composition and seasonal sex ratio of *X. kroyeri* in the São Francisco River mouth region, Northeastern Brazil, providing crucial insights for the sustainable management of this important fishery.

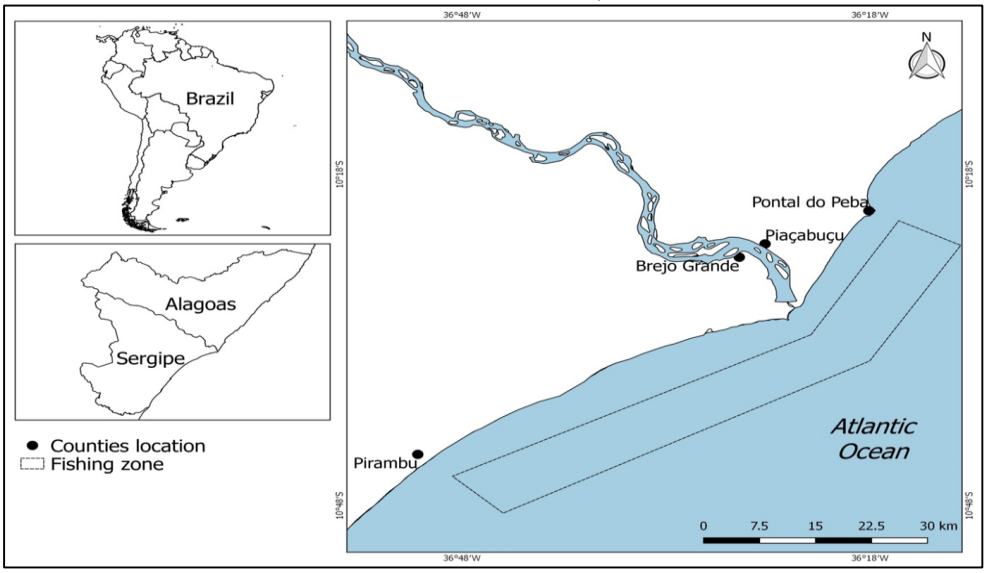
MATERIAL AND METHODS

Study area

This study was conducted through the monitoring of landings of the shrimp fleet of Pontal do Peba Beach, south coast of Alagoas (Northeast Brazil) (Figure 1), typical area of the Northeastern Brazil Marine Ecoregion as defined by Salding *et al*. (2007). The climate of the region is AS', hot and humid (Medeiros *et al*. 2007) and the fishing area is characterized by a stretch of continental shelf between the states of Alagoas and Sergipe (10º22'-10º33' S and 36º13'-36º23' W) of approximately 80 square nautical miles between the isobaths 15 to 25 m (Santos & Ivo, 1998).

This studied area is the main landing points for shrimp caught in the mouth of the São Francisco River and the shrimp fleet is a pioneer in the use of motorized double trawling with artisanal vessels in Northeastern Brazil (Santos & Ivo, 1998). The vessels used in fisheries have wooden hulls with a length varying between eight and 12 meters and act in double-rig trawls using knot-to-knot 28 mm mesh in the nets (Normative Instruction IBAMA No. 14, 10/15/2004). The vessels perform two expeditions a day in different shifts (morning and night) with different crews, in depths from 10 to 30 m.

Figure 1 – Study area with approximate Pontal do Peba's marine shrimp trawling operation limits in the São Francisco rivermouth, Northeastern Brazil



Biological Sampling

A total of 3,072 specimens of *Xiphopenaeus kroyeri* were obtained between July 2008 and November 2009 through monthly sampling and analyzed. Sampling was not carried out in December 2008 and April 2009 because these dates correspond to the closed season on shrimp fishing in the region (Normative Instruction IBAMA No. 14, 10/15/2004). After collections, the specimens were placed in plastic bags containing ice, properly labeled, and referred to the Carcinology Laboratory of the Federal University of Alagoas for further analysis.

In the laboratory, all specimens collected were classified as for sex by visualizing the external characters: the presence of a thelycum (found ventrally at the base between the fourth and fifth pair of pereiopods of female shrimps) and petasma (copulatory appendage attached to the first pair of pleopods in male shrimps) (Santos & Silva, 2008). The size of the individuals was measured considering the carapace length (CL) (distance between the base of the rostrum and the posterior margin of the carapace) using a metal caliper with an accuracy of 0.05 mm. Young individuals were those whose carapace length was smaller than 14 mm (Santos & Freitas, 2006).

Rainfall data

Rainfall data (2008-2009) was obtained by a meteorological station located near the São Francisco River mouth, in Piaçabuçu, and accessed from the Hydrological Information System of the National Water Agency (http://www.snirh.gov.br/hidroweb/serieshistoricas). This data was used to check for seasonal variations in sex ratio, size of individuals and abundance. The collection months were grouped into "dry period" (August/ 2009, September/ 2008, October/ 2008, November/ 2008, January/2009, February/ 2009, March/ 2009, September/ 2009, October/ 2009 and November/ 2009) and "rainy season" (May/2009, July/ 2009, June/ 2009, July/ 2009 and August/ 2009) based on monthly rainfall averages (mm) for the region. The definition of dry (15.27 ± 13.08 mm) and rainy (178.20 ± 94.03 mm) periods

was based on the Köppen-Geiger classification for the tropical climate (Peel *et al*. 2007), which considers the one with average monthly rainfall above 60 mm as a rainy season.

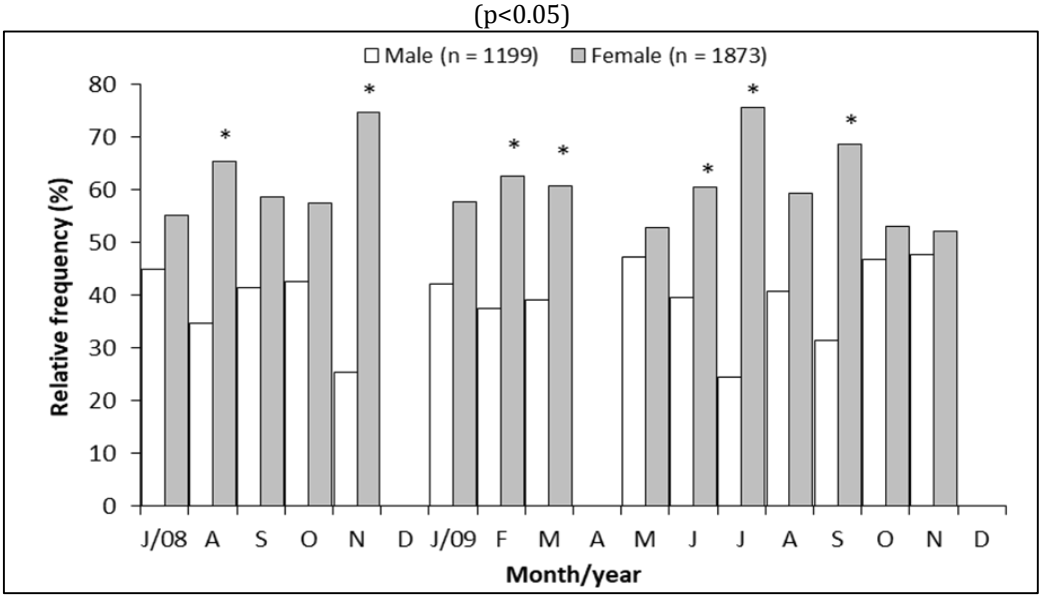
Data analysis

The size values were grouped by month, by sex, and by period (dry and rainy). All specimens were grouped into 12 carapace length classes considering 2 mm intervals, according to Sturges' rule (k=13, A/k = 1.9). The sex ratio analyses were performed considering the size, frequency of individuals, and period (dry and rainy). To check for differences in sex ratio and in the proportion of juveniles and adults in different periods, the chi-square test was used ($\chi 2$). Differences in size for sexes grouped in the dry and rainy periods were tested by the Mann-Whitney test. To test for differences in size between sexes, the t test was used. The level of significance for all tests was 0.05.

RESULTS

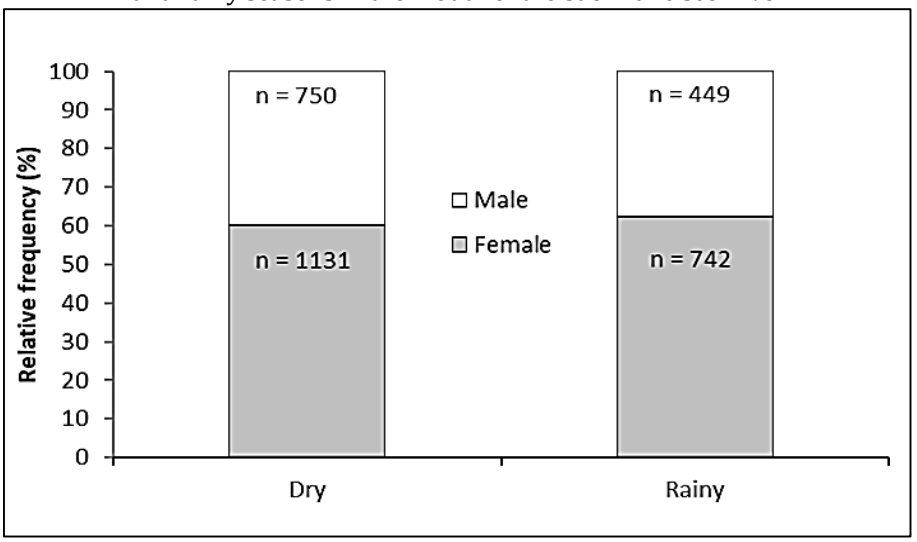
Of the 3,072 specimens of *X. kroyeri* analyzed, the number of females (61.00%) was significantly higher than that of males (39.00%) (χ^2 = 147.87; p = < 0.0001). The proportion of females was significantly higher than that of males in August 2008 (χ^2 = 28.87; p = < 0.0001), November 2008 (χ^2 = 34.50; p = < 0.0001), February 2009 (χ^2 = 11.12; p = 0.0011), March 2009 (χ^2 = 7.80; p = 0.0066), June 2009 (χ^2 = 17.24; p = < 0.0001), July 2009 (χ^2 = 74.53; p = < 0.0001), and September 2009 (χ^2 = 13.82; p = < 0.0003) (Figure 2).

Figure 2 – Monthly frequency of males and females of *Xiphopenaeus kroyeri* in the mouth of the São Francisco River between July 2008 and November 2009. (*) = significant difference (p<0.05)



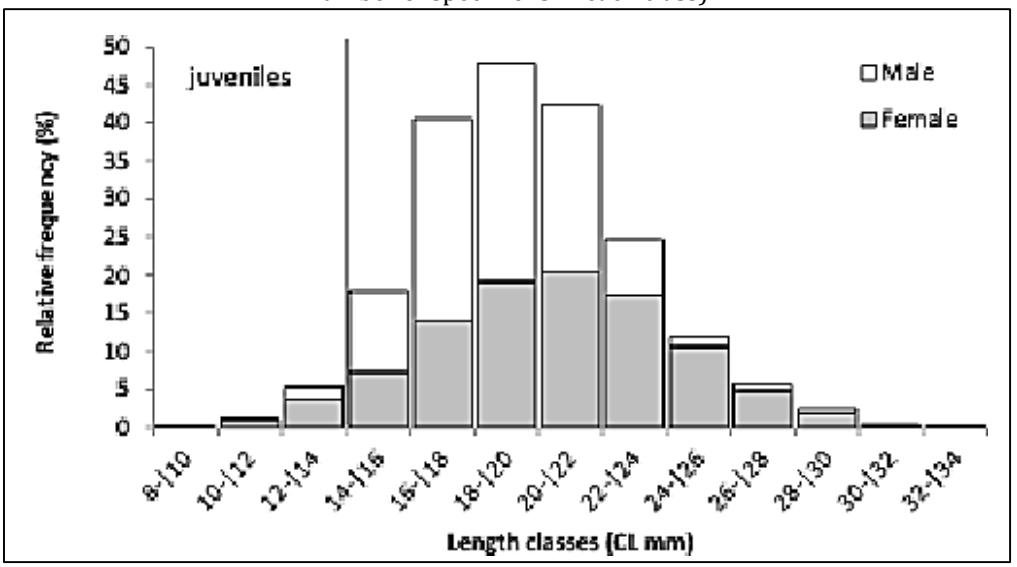
Females were predominant in both the dry season (χ^2 = 77.17; p = < 0.0001) and the rainy season (χ^2 = 72.08; p = < 0.0001) (Figure 3).

Figure 3 – Frequency of males and females of *Xiphopenaeus kroyeri* in the dry and rainy seasons in the mouth of the São Francisco River



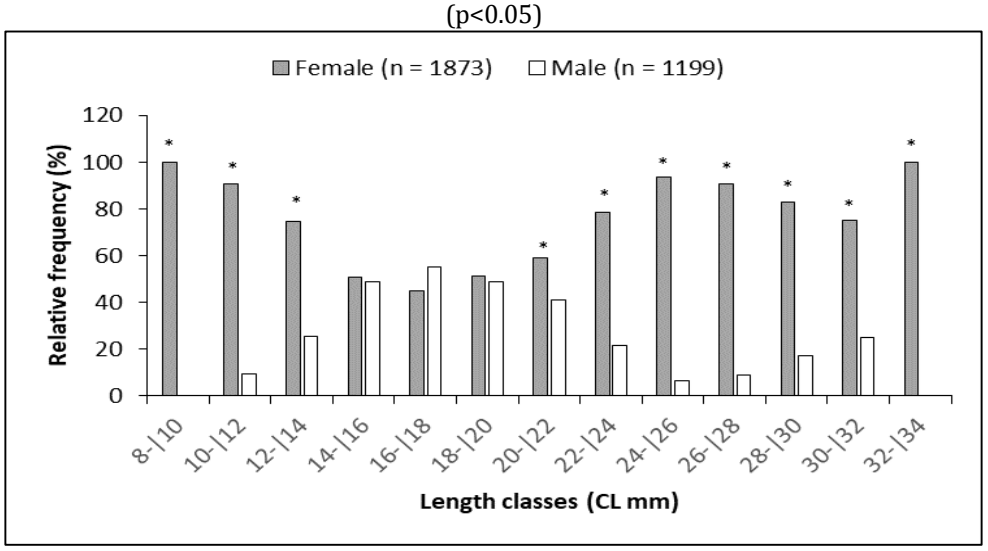
The frequency distribution by size classes showed a unimodal distribution in the 18-|20 mm class, which accounted for 23% of the collected specimens. Young specimens corresponded to only 3.5% of the population studied. There was a higher frequency of females in the 20-|22 mm class and males in the 18-|20 mm class (Figure 4).

Figure 4 – Relative frequency of male and female of *Xiphopenaeus kroyeri* by carapace size classes by sex caught in the mouth of the São Francisco River, Northeastern Brazil (N = number of specimens in each class)



Females were larger (20.34 ± 3.75 mm; t = 21.42; p = < 0.0001) than males (18.81 ± 3.88 mm) and predominant in almost all size classes. The percentage of males and females showed no statistically significant differences only in the ranges 14-|16, 16-|18, and 18-|20 and 20-|22 mm (Figure 5).

Figure 5 – Relative frequency of males and females of *Xiphopenaeus kroyeri* by carapace size classes caught in the mouth of the São Francisco River. (*) = significant difference (p<0.05)



The length of individuals in the dry period was greater than in the rainy period (p = 0.0120), with averages of 19.82 ± 3.47 mm and 19.55 ± 3.44 mm, respectively. The length presented mode in classes 18-|20 and 20-|22 mm in the dry period, unlike in the rainy period, with mode only in the class 16-|18 mm. The size of individuals in the dry period ranged from 8.50 mm to 33.99 mm and in the rainy period from 10.20 mm to 31.70 mm. There was also a higher concentration of juveniles (χ^2 = 16.64; p = < 0.0001) in the dry season (3.9%) than in the rainy season (2.7%). There was no difference in the participation of adult individuals between the different periods (χ^2= 0.007; p = 0.9885).

DISCUSSION

The proportion of females was higher than that of males in almost all sizes and months sampled. Traditionally, the sex ratio can be estimated by comparing the total number of males and females in a sample, being an indicator of a possible breeding area when the proportion of males and females is close, as in nature the male-to-female ratio is approximately 1:1 (Lopes *et al*., 2010). In commercial catches targeting *Xiphopenaeus kroyeri*, the predominance of females in sex ratio is common and seems to be a tendency (Santos *et al*., 2006; Santos & Silva, 2008). However, such a result can be influenced by the selection of shrimp captured by fishermen, who end up selecting larger individuals, mostly females.

Miazaki *et al*. (2021) observed in a study realized in southeastern coast of Brazil, that growth parameters differ between sexes: males reached smaller sizes, have larger growth coefficients (k) and higher mortality. However, Lopes *et al*. (2014), in a study conducted in northeastern coast of Brazil, found that females of *X. kroyeri* had higher total mortality than males. This could indicate differential migration (common in certain penaeids) in different locations where trawling occurs. Therefore, different mortality rates observed between the sexes can influence the sex ratio results.

Studies confirm that the dominance of females on fleet landings occurs regardless of rainfall (Reis Jr. *et al*. 2019; Lopes *et al*., 2014). However, on the coast of Sergipe, Santos *et al*. (2001) reported a possible positive influence of rainfall dynamics on the penaeid stocks, contributing to the survival of the species, mainly at the larval phase. During the

winter period, Santos & Coelho (1998) identified the largest recruitment pulse for this species in the study area. In this period, the individuals effectively start to contribute to the population's capturable biomass, and the size and age are determined by the selectivity of the fishing gear.

Miazaki *et al*. (2021) highlight that the evaluation of growth and mortality parameters based on the von Bertalanffy growth model is essential for fishery stock management. Estimates of mortality and exploitation rates, based on growth parameters, are crucial for monitoring and implementing management plans that maintain stocks at sustainable levels in the long term (Pauly, 1980; King, 2007). Recent studies have shown that the increase in industrial and artisanal estuarine fishing, combined with low effectiveness of fishing legislation, led to the collapse of pink shrimp *Farfantepenaeus* spp. stocks in the late 1990s (D'Incao *et al*., 2002). Consequently, the seabob shrimp *Xiphopenaeus kroyeri* became the main target of fishing on the southeastern Brazilian coast (Costa *et al*., 2007; Simões *et al*., 2010).

The higher number of juvenile individuals recorded here in the dry period is similar to the number found by Lopes *et al*. (2014) on the coast of Pernambuco. The authors reported the presence of smaller shrimp in August and September. Additionally, the greater presence of juveniles may also be related to the area where trawling occurs during this period (closer to the coast). Castro *et al*. (2005) found that recruitment for this species occurs preferentially in coastal areas throughout the year. In the region, the adopted management corresponds to the closed season, based on studies on the species recruitment occurring in two stages: from April 1st to May 15th and from December 1st to December 15th January, in accordance with the Normative Instruction of the MMA (Ministry of the Environment) n. 14 of 23 October 1992 (IBAMA, 2004).

Indeed, the percentage of juveniles was lower than that of adults in all indicating that the fishing activity operates predominantly over the adult stock of this seabob shrimp species. Santos *et al*. (2006) mention sea fishing targeting the seabob shrimp, which in the Northeast actuate intensively over the adult stock and that the concentrations of juveniles in fishing undergo subtle variations during the year and in different locations. The presence of juveniles is common throughout the year, as this species has continuous recruitment (Santos & Coelho, 1998).

However, despite the presence of few young individuals in the samples, recruitment potential can be reduced by overfishing the breeding stocks (Lopes *et al*., 2014). Therefore, further studies are needed to analyze the fishing efforts to which *X. kroyeri* populations are subjected, coupled with information on their population structure, to implement new management measures that enable stock maintenance and the viability of this important fishery.

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