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Original Article

Ecological and reproductive parameters of the seabob shrimp, *Xiphopenaeus* spp. (Heller, 1862) on the southern coast of the state of Espírito Santo, Brazil: potential use of less sampling effort

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ABSTRACT

The study investigated the population parameters of the shrimp *Xiphopenaeus* spp. (commonly known as seabob shrimp) in Anchieta, south coast of the state of Espírito Santo, Brazil, focusing on reducing the sampling effort. Shrimp were collected between February 2013 and February 2015. Individuals were measured, analyzed for sex and stage of reproductive development. In total, 1,564 individuals were analyzed in Anchieta, 534 males (74 juveniles and 460 adults) and 663 females (88 juveniles and 575 adults), and 367 individuals were not identified to sex or maturity. Significant differences were observed in shrimp abundance, with higher catches at the shallowest sampling point and associated with the type of substrate (silt+clay), while in the rainy season (September to March) and dry season (April to August) there were no significant differences. Despite this, greater abundances were found in the rainy season. The sex ratio was 0.80♂: 1♀. Carapace length ranged from 5.7 to 28.9 mm, with larger sizes recorded for females, as well as a larger size at first maturation than males, 12.86 and 11.60 mm respectively. All stages of development of the seabob shrimp were observed at the sampling points and periods, which represents a pattern of continuous reproduction and recruitment of the species in the area. Considering the sample size used, which is comparatively smaller than other studies, all estimates confirm current knowledge about the biology of the species and provide robust data on the seabob shrimp off the Anchieta coast, which are necessary for management and conservation.

KEYWORDS

Abundance, conservation, Penaeoidea, recruitment, size

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INTRODUCTION

The superfamily Penaeoidea is known for having several species of fishing importance, and removing these shrimps from coastal environments, in tropical and subtropical regions, by artisanal fisheries has occurred historically since the second half of the 20th century (Ferrão Santos and Arlindo Pereira, 2004). Since the 1950's, small-scale shrimp fishing with motorboats has expanded worldwide, gained prominence in the economic sector, and reached high yields (Ferrão Santos and Arlindo Pereira, 2004; FAO, 2018). In the southern region of the state of Espírito Santo, this fishing activity is considered economically relevant, since it generates income and employment for the riverside communities (Freitas Netto and Di Beneditto, 2007). On the Southeast and South coast of Brazil, shrimp fishing catches mainly the pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817); *Farfantepenaeus paulensis* (Perez-Farfante, 1967); *Artemesia longinaris* Spence Bate, 1888; white shrimp *Litopenaeus schmitti* (Burkenroad, 1936) and the seabob shrimp *Xiphopenaeus* spp. (Heller, 1862) (D'Incao et al., 2002; Braga and Zappes, 2021). Braga et al. (2018), Musiello-Fernandes et al. (2020) and Braga and Zappes (2021), studying the traditional knowledge of fishermen on the Coast of Espírito Santo (ES), reported that these fishermen work primarily with trawl fishing to catch seabob, pink and white shrimp.

Among the shrimps caught in Brazil, the seabob stands out due to its high abundance in coastal environments (Fernandes et al., 2011; FIPERJ, 2013; Boos et al., 2016), accounting for 27% of the total sea extractive fishery for crustaceans (Castro et al.,2005; Boletim Estatístico da Pesca e Aquicultura, 2011). Additionally, this shrimp is the third most widely used sea extractive fishery resource in southeastern Brazil, behind only the *Sardinella brasiliensis* (Steindachner, 1879) and the meagre *Micropogonias furnieri* (Desmarest, 1823) (Heckler et al., 2013).

The seabob shrimp have a continuous distribution in the western Atlantic Ocean, occurring from the state of Virginia in the United States of America (~36ºN 75'W) to the state of Rio Grande do Sul, Brazil (~30ºS 53'W) at depths of up to 30m (Costa et al., 2003), and does not have recruitment migrations between the estuarine and marine environment during the life cycle, as happens with several species of peneids (Dall et al., 1990). The maturation and spawning of individuals take place in waters farther from the coast, while growth is associated with shallow regions near the coast (Branco et al., 1999; Branco, 2005; Castilho et al., 2015). Conceptions of the latitudinal variation of periodic breeding patterns in near-shore marine oceanographic animals have been useful in suggesting underlying environmental factors that might affect the observed patterns.

Surveys on the biology and fishing of *Xiphopenaeus* spp. were also conducted along the Brazilian coast. The information confirms the high reproductive capacity (Martins et al.,2013; Heckler et al.,2018), frequency of recruitment (Campos et al., 2011), tolerance to different environmental conditions such as temperature variation, salinity (Castilho et al., 2008; Branco et al., 2018), food plasticity, being classified as an opportunistic omnivorous animal (Branco and Moritz Jr, 2001; Willems et al., 2016), and spatial genetic flow (Voloch and Sole-Cava, 2005; Gusmão et al., 2006). In general, the variability of the species may hinder the management of fisheries on a large scale, not achieving objectives that ensure sustainability. Therefore, regional research to ensure knowledge of the species biology is essential to adjust the management of this fishing resource (Martins et al., 2013).

Studies on shrimp population and reproductive biology provide data about the recruitment period, gonadal maturation stages, reproductive peaks and sex ratio of commercially-exploited populations (Castro et al., 2005; Almeida et al., 2012; Heckler et al., 2013; Martins et al., 2013; Heckler et al., 2018), however, it is important to establish a minimum amount of sampling to be analyzed in order not to jeopardize the conservation and maintenance of natural shrimp stocks. Historically, studies in Brazil involving shrimp capture large amounts of individuals to estimate population parameters (e.g. Castro et al., 2005; Almeida et al., 2012; Heckler et al., 2013; Martins et al., 2013; Heckler et al., 2018); however, estimates with a large sample effort in areas with declining catch stocks may not be possible. Therefore, this study aims to characterize the spatial-temporal distribution and the population and reproductive biology of the seabob shrimp sampled in Anchieta south coast of Espírito Santo, and also aims to evaluate the potential use of less sampling effort to understand the biology of the seabob shrimp. Baseline studies like this are essential to provide information needed for handling and conservation of the species.

MATERIAL AND METHODS

Sampling Area

The fishing port of Anchieta is located on the southern coastal region of the state of Espírito Santo (Fig. 1) and stands out for its mining activities and mariculture and artisanal fishing practices. The region is characterized by the influence of the Benevente River, with an average flow rate of 30 m^3/s, an important nutrient carrier for the region (ICMBio, 2018). Rainfall is around 1200 mm/year (Ferreira Junior et al., 2008), with rainy summers and dry winters and surface water temperature ranging from 23.7 to 25.5 °C (Sá et al., 2007).

Data Collection

The collections of the seabob shrimps, under authorization of the Brazilian Institute for the Environment and Renewable Natural Resources - IBAMA (SISBio/ICMBio No 29413-1), were done quarterly from February 2013 to February 2015, comprising rainy seasons (September to March) and dry seasons (August to September) according to Alvarenga et al. (2012). The shrimps were caught by fishing boat equipped with otter trawls with funnel-shaped nets, that are eight meters high, seven to nine meters wide at the mouth and a mesh size that varies between five and 25 mm (Braga et al., 2021a). The average speed of each bottom trawl was two knots, lasting 30 minutes, at depths of 2 m, 5 m and 10 m. The depths represent three sampling points, P1, P2 and P3, respectively (Fig. 1). From each trawl, the total weight (g) of *Xiphopenaeus* spp. was obtained and a 300g subsample, representing the portion of shrimp exploited by fishing. These specimens were randomly separated to count the number of individuals, sex classification and stage of gonadal development, and measurement of the length of the carapace (0.01 mm). Carapace length was measured from the posterior orbital margin to the end of the posterior cephalothorax margin. Sex was identified as described by Costa et al. (2003). The reproductive status of the females was determined from the macroscopic observation of the gonads. Four developmental stages were distinguished: IM = immature; RU = rudimentary adults with thin, whitish-looking gonads; ED = in development; and DE = developed (Castilho et al., 2007). In males, we examined the condition of the endopods of the first pair of abdominal appendages: when separated, individuals were classified as juvenile or immature (IM); when united and forming the petasma, individuals were classified as adults (Boschi and Scelzo, 1977). Adult males were also classified as rudimentary (RU) if the terminal ampoules were empty; in development (ED) when the terminal ampoules were partially filled with substance; and developed (DE) when the terminal vesicles were completely filled with substance.

For environmental factors (temperature and salinity), surface and bottom water was collected at each sampling point and period using a Van Dorn bottle. The temperature (°C) was measured with a mercury column thermometer and the salinity (‰) with an optical refractometer. For granulometry and organic matter analysis, sediment was collected using a Van Veen grab at each point and collection period. Two 100 g samples were sieved in a mechanical vibrator with seven sieves in order to determine the granulometric fractions of the sediment: gravel, coarse sand, medium sand, fine sand, very fine sand, silt + clay. From the percentage of the granulometric fractions of each sampling point, the central tendency measures (phi) were calculated, which determine the most frequent granulometric fraction in the sediment. The classification obtained was: gravel (-1); coarse sand (0); medium sand (1); fine sand (2); very fine sand (3) and silt and clay (≥ 4) (Castilho et al., 2008). The percentage of organic matter content was obtained from the ash free dry weight, and three 10g sub-samples were taken from the substrate at each sampling point. The sub-samples were incinerated at 500 °C for three hours in a muffle furnace, after which their dry weight was obtained (Magliocca and Kutner, 1965).

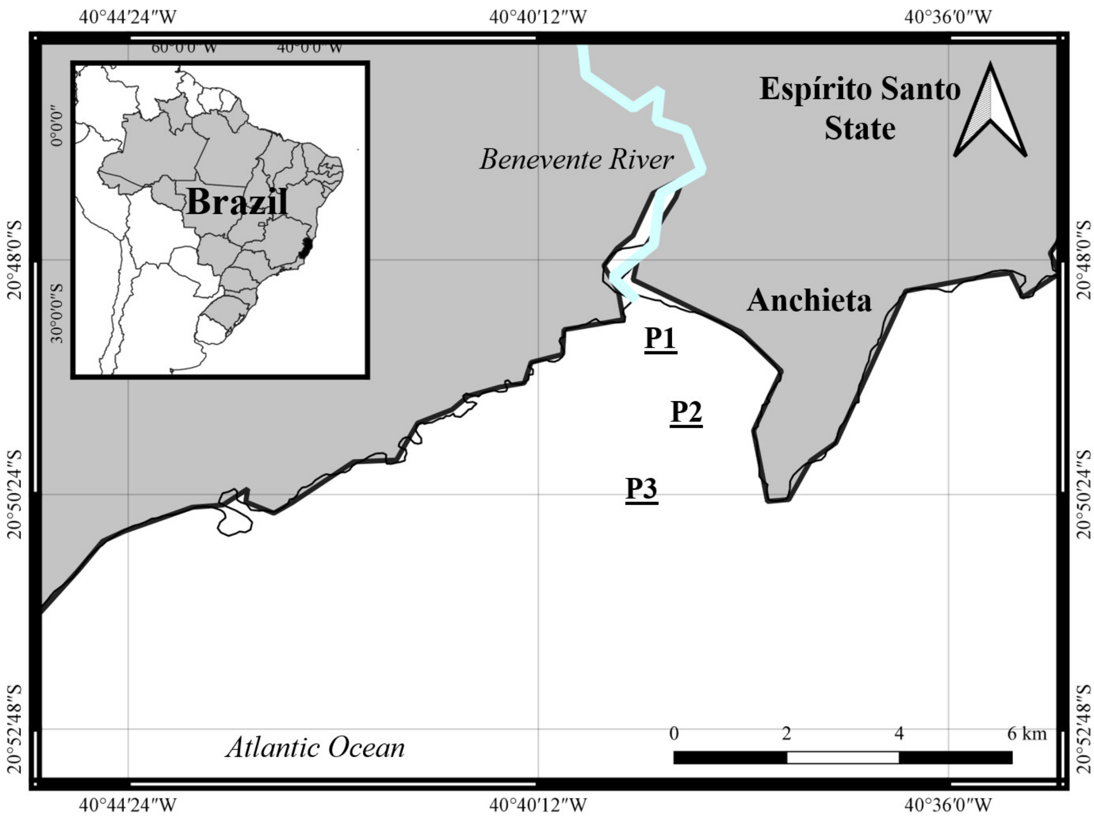

Figure 1. Map of Brazil highlighting the state of Espírito Santo and the fishing port of Anchieta, indicating the sampling points of the seabob shrimp. (P1 = Point 1: 2m; P2 = Point 2: 5m; P3 = Point 3: 10m; blue line = Benevente River).

Data Analysis

The differences in the data of abiotic factors for the points and seasons (rainy/dry periods) were compared by means of analysis of variance (ANOVA). The influence of environmental variables (temperature, salinity, particle size and organic matter) on shrimp abundance were analyzed by principal component analysis (PCA) using packages of Le et al. (2008) and Kassambara and Mundt (2020). The normality of the data was verified by Shapiro-Wilk test. The Two-Way ANOVA was used to investigate the effects of different categories (sex and maturity) and the Tukey test (α = 5%) to distinguish equality or difference between factors. Sex ratio was analyzed using only adult shrimps from sampling points, compared to the nonparametric Chi-squared (χ^2) test with expected ratios of 1:1 (α = 5%).

The population structure was evaluated based on the sub-samples collected per sampling point and season (rainy/dry) in order to follow the spatial and temporal variations of the stock size frequency distribution. The shrimps were grouped in 12 size classes with 2 mm intervals obtained through the formula: $At = \frac{(\text{Upper limit} - \text{Lower limit})}{K}$

Where K is the number of classes. Recruitment was observed as the entry of juvenile individuals into the population during the study period (Sturges, 1926). The formula: $y = \frac{1}{1 + e^{[-r\,(LC - LC50)]}}$ was used to identify the first maturation size of males and females, where y is the estimated ratio of adult shrimps, LC_{50} is the carapace size in 50% of individuals reaching sexual maturity, and r is the coefficient for the slope of the logistic curve. The average size in which 50% of the population reaches sexual maturity was determined by adjusting the logistic model - LC_{50} (Fonteles-Filho, 2011). The logistic curve was adjusted by the method of least squares to the ratios of the size classes of all individuals and samples using interactions of maximum probability. The results were analyzed using the R program (R Core Team, 2020).

A systematic review of the literature was carried out to compare the efficiency of the sampling number of the seabob shrimp (*Xiphopenaeus* spp.) with the present work as a study model to reduce the sampling effort with other commercially exploited penaeid species. Reference lists were found on Google Scholar, Scielo, Scirus, Science Direct. A total of seven articles composed the set of references (Tab. 2). Each article was evaluated to identify the type of net used and the number of shrimps sampled. The power analysis for proportions of two samples with independent sample sizes was calculated considering the sample number of articles (Cohen, 1988).

RESULTS

The average values of the environmental parameters recorded at the sampling points were: temperature 23 °C ± 0.7, salinity 36.4‰ ± 0.5 and organic matter 25.6% ± 1.3. And for the seasons, namely: temperature 23 °C ± 0.5, salinity 36.0‰ ± 0.7 and organic matter 26.0% ± 0.7. No significant differences in the environmental parameters registered at the collection points, such as temperature ($F = 0.49$, $p = 0.61$), salinity ($F = 0.27$, $p = 0.76$) and organic matter ($F = 0.78$, $p = 0.46$) and in the rainy and dry periods, namely: temperature ($F = 0.36$, $p = 0.56$); salinity ($F = 0.38$, $p = 0.54$) and organic matter ($F = 0.38$, $p = 0.55$). There was no significant difference in the granulometric fractions of the sediment between the points ($F = 0.03$, $p = 0.98$) and sampling period ($F = 0.002$, $p = 0.96$). However, higher concentrations of silt+clay were observed in P1 (57.5%), phi values 3.7 ± 1.5, 2.6 ± 1.0 and 2.8 ± 1.2 for P1, P2 and P3 respectively. The rainy period showed the highest percentages of finer sediment in relation to the dry period, phi value 3.4 ± 2.0, 2.5 ± 1.5.

During the study period, 1,564 sea shrimps were analyzed in Anchieta, 74 juvenile males, 460 adult males, 88 juvenile females and 575 adult females, with 367 individuals not identified to sex or maturity. Considering all sexed individuals and adults, the sex ratio was 0.80♂:1♀, for juveniles the sex ratio was 0.84♂:1♀, and did not differ between sampling depths with a mean of 0.84♂:1♀ ($\chi^2 = 3.77$, $p = 0.15$). The sex ratio in the rainy season was 0.72♂:1♀, while in the dry season it was 0.92♂:1♀ ($\chi^2 = 4.08$, $p = 0.045$).

The individuals were caught at all sampling points and collection periods. The highest abundances were recorded at shallower depths (P1) and were significant (ANOVA, $F = 8.46$, $p = 0.01$). On the other hand, there was no difference between the sampled periods (ANOVA, $F = 0.051$, $p = 0.83$), but the highest abundance was recorded in the rainy period (Fig. 2). The Principal Component Analysis (PCA) was applied only where the differences in shrimp abundance were significant. The main related factor was the type of sediment. Organic matter was the only factor negatively correlated with shrimp abundance. In total, the axis PCA1 (47.9%) and PCA2 (34.8%) explained 82.7% of the total variance (Fig. 3).

Table 1. Spatio-temporal patterns of ovarian maturity and juvenile recruitment of *Xiphopenaeus* spp. at different latitudes mentioned in the literature and observed in the present study.

Authors	Mature Ovary	Recruitment	CL (mm)	Male $CL_{50(mm)}$	Female $CL_{50(mm)}$	Kind of study	Location (Brazil)
Branco et al., 1999	summer spring	autumn winter	–	–	–	continuous	Foz do Rio Itajaí-Açú – SC
Castilho et al., 2015	autumn winter	summer spring	4.3 – 35.0	10.2	12.4	continuous	Ubatuba Bay, SP
Castro et al., 2005	summer autumn	summer spring	3.8 – 36.8	–	–	continuous	Ubatuba Bay, SP
Heckler et al., 2013	summer spring	summer	4.5 – 30.0	11.00	13.00	continuous	Ubatuba Bay, SP
Present study	autumn winter	summer winter	5.7 – 28.9	11.60	12.86	seasonal	Anchieta, ES

CL = Length of cephalothorax. Dashes mean that the cephalothorax length was not specified in the study.

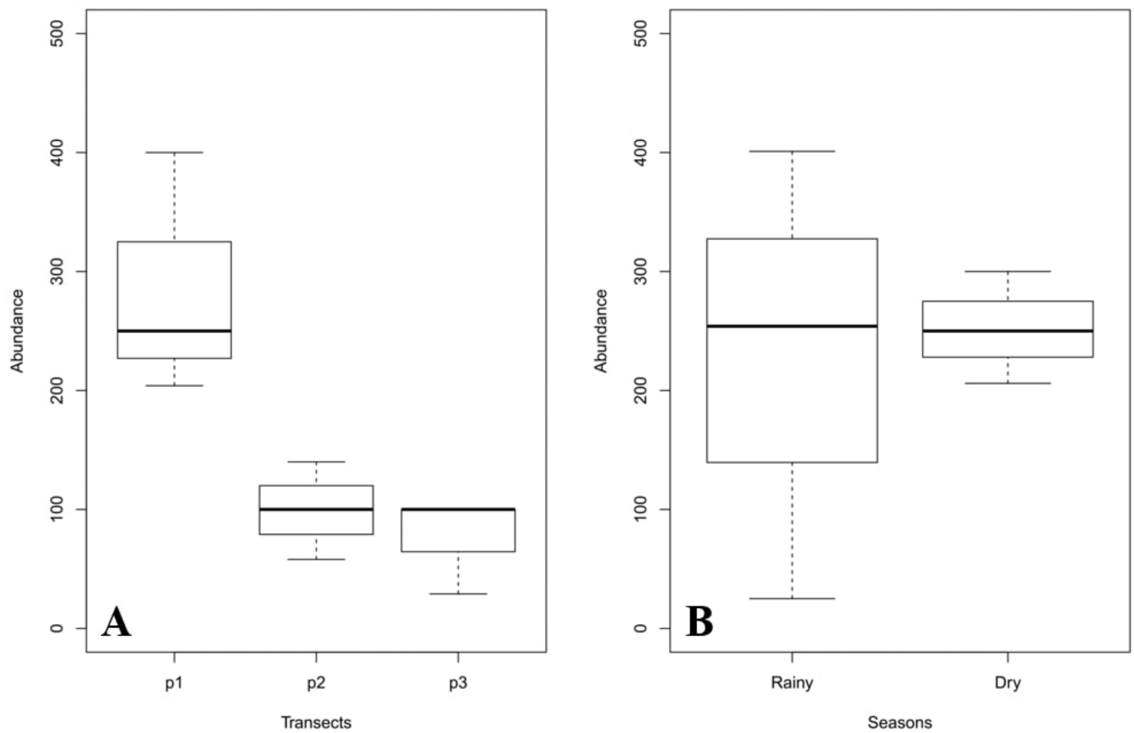

Figure 2. Boxplot of *Xiphopenaeus* spp. abundance at each collection point = transects, (**A**) and season (**B**) between February/2013 and February/2015. p1: Point 1; p2: Point 2; p3: Point 3. *Statistically significant difference.

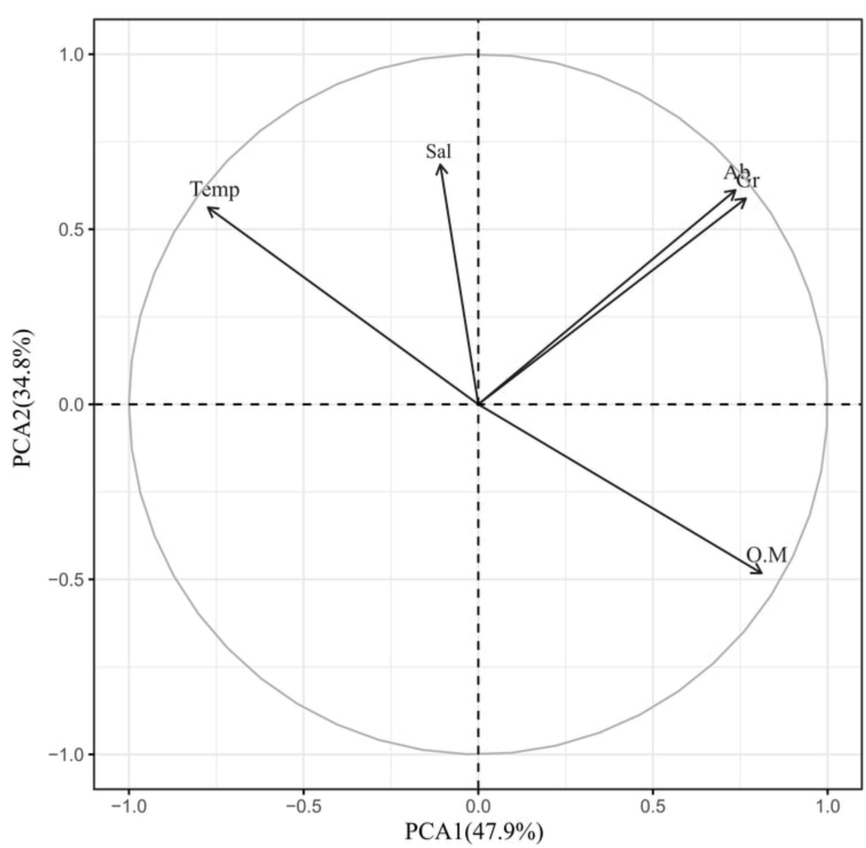

Figure 3. Principal component analysis (PCA) for *Xiphopenaeus* spp. abundance and environmental variables in Anchieta region. The samples were collected between February/2013 and February/2015. Ab: Abundance; Gr: Granulometry; O.M: Organic Matter; Sal: Salinity: Temp: Temperature.

The carapace length (LC) varied from 7.6 – 27.3 mm for male shrimps and 5.7 – 28.9 mm for females. The analysis of variance showed a difference in carapace length between sexes (ANOVA: F = 4.58, p = 0.032), with female shrimps showing the longest carapaces compared to males, 17.2 mm ± 0.18 LC and 16.4 mm ± 0.14 LC, respectively. The carapace length where 50% of males and females were considered mature (morphological gonadal maturity) was estimated at 11.60 and 12.86 mm, respectively (Fig. 4).

The carapace size samples were grouped at seasonal intervals to check for differences in growth parameters (Fig. 5). A total of 1,197 specimens were analyzed, which fit the category of sex (male, female), maturity (juvenile, adult) and had the carapace length measured. Larger amounts of individuals were captured in the rainy season, especially in spring. Size classes showed presence of the juveniles throughout the study period except in the summer of 2015. Peaks were observed in the summer and winter of 2013 and spring of 2014. Considering morphological maturity, females were predominant among juveniles in 2013 and males in 2014. In general, females reached the larger classes.

Percentage values of maturation stages are shown in Figure 6. Adult specimens (RU, ED and DE) were predominant in both sexes, and the highest representation of immature specimens was recorded in point 1 (males 19.1% and females 17.8%) while males and females in DE stage were the majority in P2, 26.8 and 34.1%, respectively. Significant differences were observed between the sampling points (ANOVA, F = 10.35, p = 0.0001), and seasons (ANOVA, F = 18.15, p = 0.0001). During the collection period (dry and rainy), adult shrimps were observed at all stages of development. The highest representation of immature shrimps was recorded in the rainy season (males 16.1% and females 18.6%), while males and females with DE stage were predominant in the dry period (22.2 and 8.5%, in that order).

The power analysis estimates that the sample number of 1000 individuals was greater than power = 0.80, which is 0.05 for this analysis. (Fig. 7). This analysis allows estimating the ideal sample size to reliably detect a given effect that is considered relevant. The difference between the means of the two groups is less than 0.2 d, in this sense the difference is negligible, even if there are statistically significant differences in the sample number.

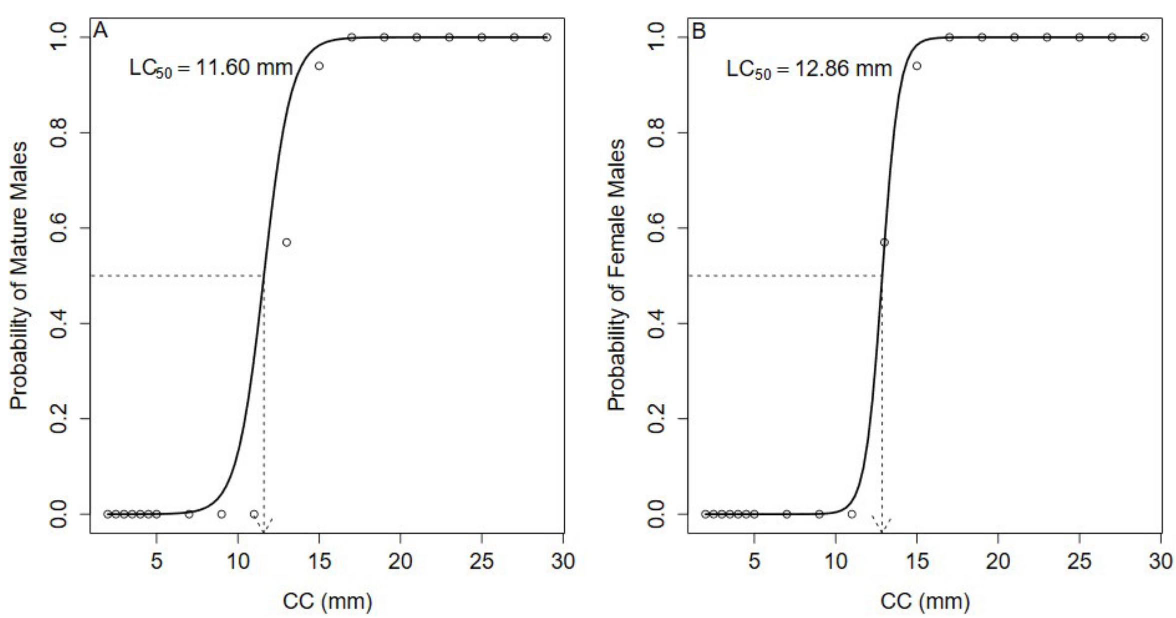

Figure 4. Carapace length (LC) of males (**A**) and females (**B**) upon reaching sexual maturity estimated by logistic regression based on the absence (0) or presence (1) of specific morphological sexual characters plotted as a function of carapace length (mm) of *Xiphopenaeus* spp. in Anchieta, southern coast of Espírito Santo, Brazil (LC_{50} = Length that 50% of individuals reach in adult size).

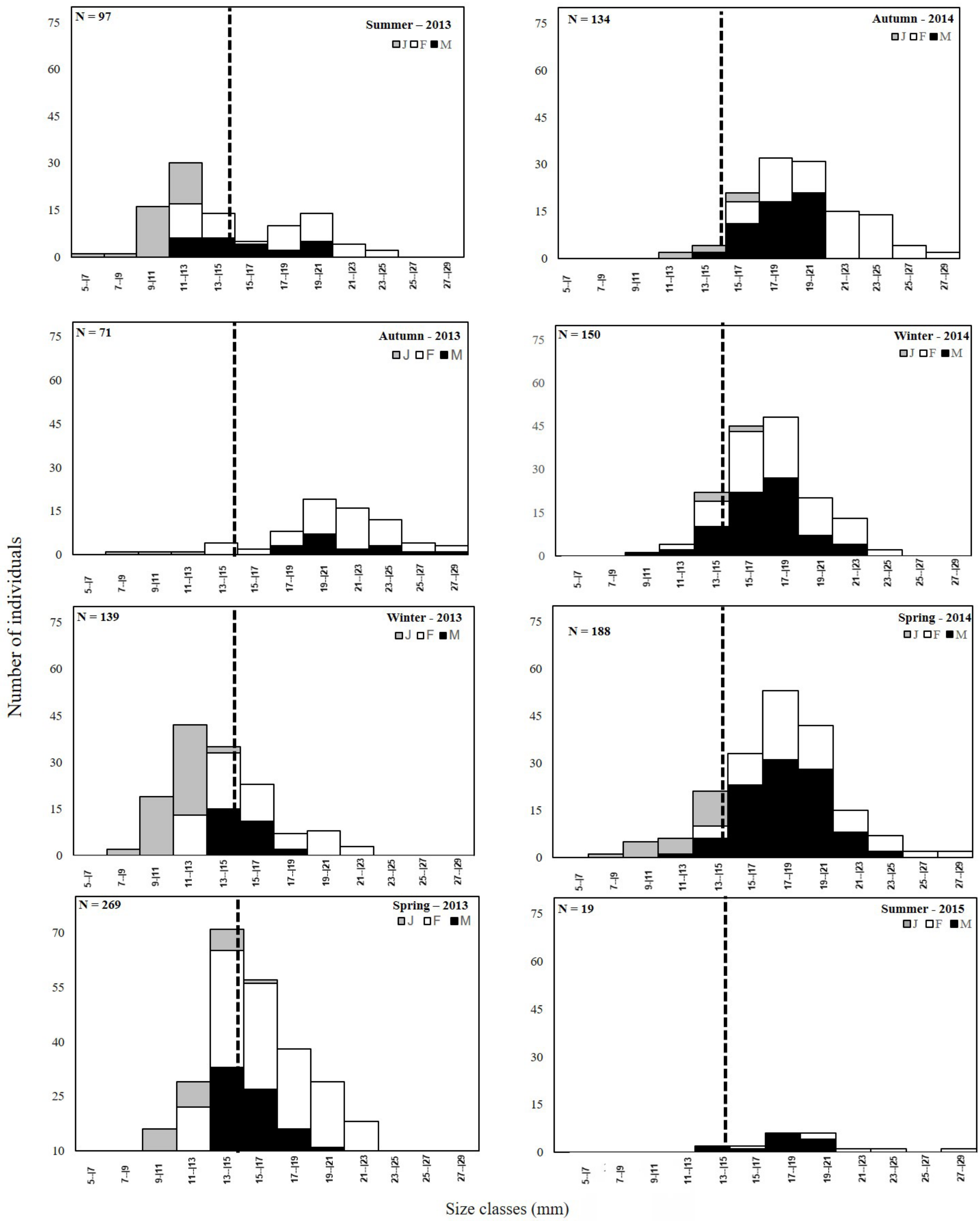

Figure 5. Frequency of the carapace size of the *Xiphopenaeus* spp. shrimp collected from February/2013 to February/2015. M: Male, F: Female, J: Juvenile. The dashed line indicates the LC_{50} as reference.

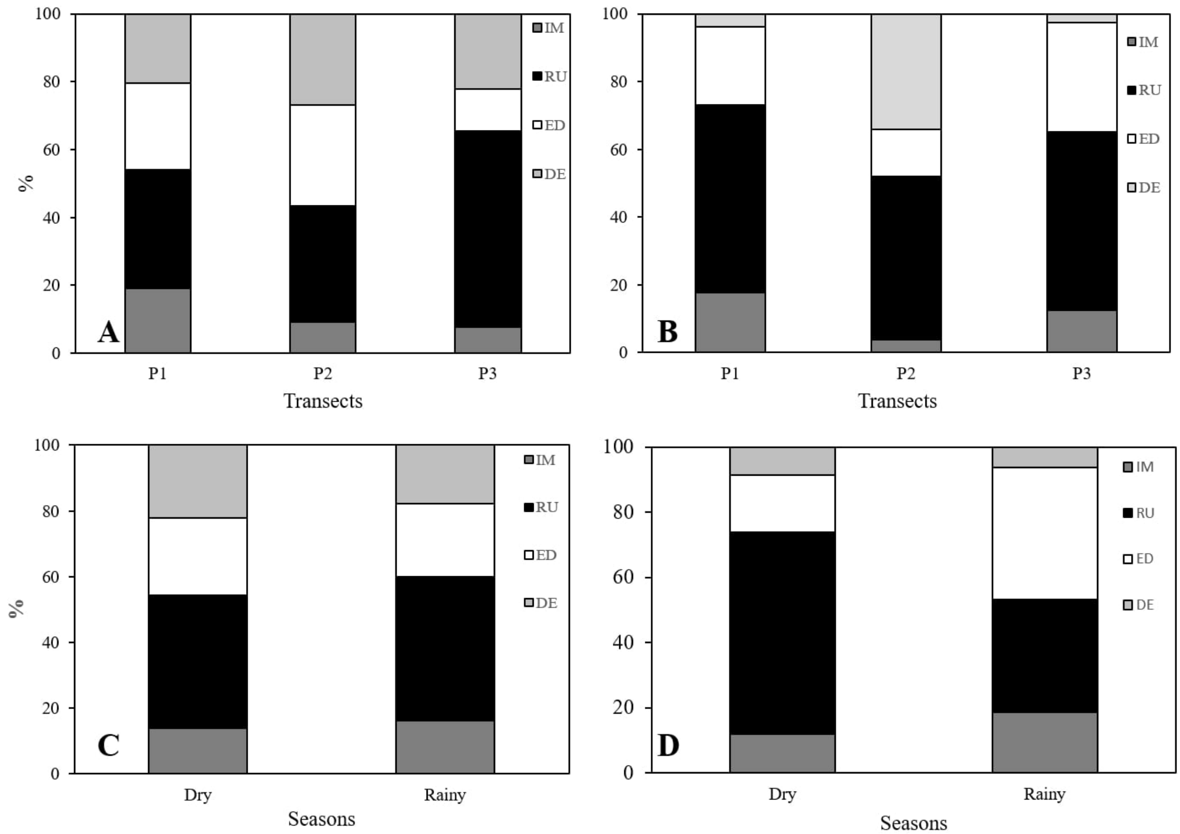

Figure 6. Percentage values of gonadal development stages of *Xiphopenaeus* spp. at sampling points = transects, (**A** and **B**) and sampling period (**C** and **D**). Males (**A** and **C**) and females (**B** and **D**). Immature (IM), rudimentary (RU), developing (ED) and developed (DE) at each sampling point from February/2013 to February/2015. P1: Point 1, P2: Point 2, P3: Point 3.

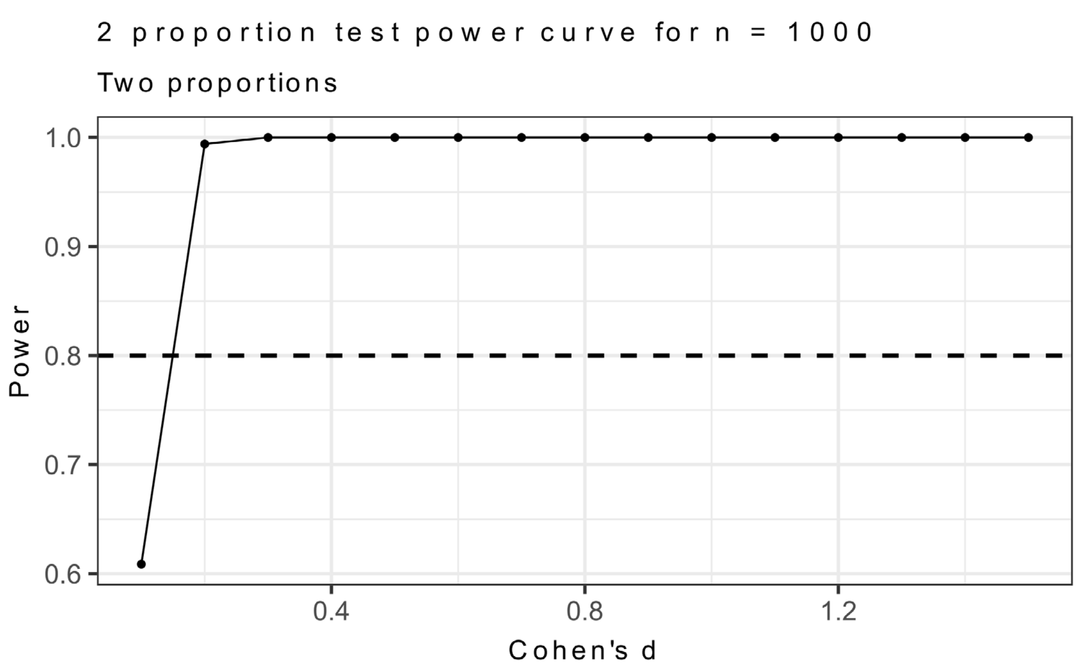

Figure 7. Cohen's power curve for evaluating the sample size of two samples.

DISCUSSION

In the state of Espírito Santo, Anchieta hosts a small fishing community with a multi-species fleet that supplies the nearby localities (Braga et al., 2018; 2021). The region's environment is characterized by a closed bay capturing the Benevente River, which is the region's main nutrient supply, since it has a mangrove area around it that develops into an estuary. Despite the dynamics of this river, the average values of abiotic factors such as temperature, water salinity, granulometry and organic matter did not differ between the points and periods studied and, even with the proximity of the sites to the mouth of Benevente River, the fresh water supply did not influence the variation in salinity, which remained between 33‰ and 40‰, probably due to the collection having occurred during the period of high tide and/or the small flow of the river (~15 m/s). However, the higher percentage of silt+clay (P1) and very fine and fine sand (P2/P3), recorded in the sampled points can be explained by the transport of sediment from the mangroves and estuaries of Benevente River. The low annual variation in environmental data (temperature, salinity, organic matter) may be related to the presence of continental barriers (Ponta de Castelhanos and Ponta de UBU) that prevent a high circulation of water and currents from the sea in these locations, providing a balanced environment.

Some authors report that salinity, sediment type and water temperature are determining factors in the distribution of Penaeoidea (Costa and Fransozo, 2004; Fransozo et al., 2004; Castilho et al., 2008). The preferred areas of occurrence of the seabob shrimp are marine environments with up to 30 m depth and sand and mud bottom, water temperature between 15 °C and 30 °C and salinity between 9.0‰ and 36.5 ‰ (Branco et al., 1999; Branco, 2005). Thus, the environmental conditions found along the Anchieta coast are regarded as optimal for the permanence and development of the seabob shrimp.

The species was sampled at all points and had greater abundance at P1 (61%). This representation is related to the granulometric fractions of the sediment, since *Xiphopenaeus* spp. preferably occupy regions with finer sediments. The P1 is characterized by a higher percentage of silt+clay and very fine sand (S+A>AMF). This type of sediment plays an essential role in the biology of the seabob shrimp, which has the habit of burying itself, and that according to Costa et al. (2007) and Freire et al. (2011), the species has this behavior as a form of defense against possible predators or environmental changes.

The greater abundance of *Xiphopenaeus* spp. recorded in the rainy season (September to March) may be related to the seasonal closure for the species, when fishing is suspended from November 15 to January 15 and April 1 to May 31 in the state of Espírito Santo (In IBAMA No 189, of September 23, 2008), aiming to protect the recruits and ensure the maintenance of natural stock. According to Braga et al. (2021), artisanal fishing in Anchieta occurs daily between one and four hours, throughout the year, except during the seasonal closure. That way, with the decrease in trawls during this period, there may be a significant increase in the population of seabob shrimp, promoting the maintenance of fishing for this species. In addition, the increase in rainfall in the rainy season directly influences the transport of finer sediments to the coastal region, a fundamental characteristic for the life of this species. This fact may also be associated with the increase in shrimp capture in the region in the spring.

The sex ratio close to 1:1 and the larger size of females compared to males observed in this study corroborates the results obtained by Eutrópio et al. (2013), who analyzed the population of seabob shrimp in Anchieta region. It is also in line with the pattern for other penaeid shrimp species (Semensato and Di Beneditto, 2008; Corrêa and Martinelli, 2009; Fernandes et al., 2011; Heckler et al., 2013). The largest recorded size for females of *Xiphopenaeus* spp. in this study was also found in studies conducted in other regions of the Brazilian coast (Branco, 2005; Castro et al., 2005; Fernandes et al., 2011; Eutrópio et al., 2013; Heckler et al., 2013). This difference in size is related to the reproduction process, where females have greater energy devoted to growth due to the need for a larger carapace size to produce oocytes, and consequently, this increases the fertility of the species. This pattern of larger female shrimp size is considered common among Dendobranchiata shrimps (Costa and Fransozo, 2004; Castilho et al., 2007; Fernandes et al., 2011).

By analyzing the annual distribution of the total length frequencies and simultaneously considering the estimated values for males and females of size at first maturity, it can be seen that the artisanal fishing effort in Anchieta is basically concentrated on the adult stock. The population structure of the seabob shrimp showed a unimodal pattern and tended toward bimodality, observed mainly in the summer, fall and winter of 2013. Unimodality reflects a continuous recruitment with entry of individuals to the population throughout the year, higher peaks may occur at certain times of the year, and constant mortality rates in the population (Díaz and Conde, 1989; Litulo, 2005). Bimodality, or polymodality, reflects recruitment pulses, differential mortality and differential behavior, and may result from the migration of individuals at a certain time of the year, in search of places more conducive to their survival (Litulo, 2005).

According to Spivak et al. (1991), the species of crustaceans that inhabit higher latitudes show seasonal recruitment or migration, characteristic of a bimodal population. On the other hand, at lower latitudes, there is a continuous recruitment of individuals, as can also be seen in the present study (Anchieta ~20 °S). A similar result was found by Eutrópio et al. (2013), which confirms the continuous reproduction described for the species in the study area. In general, tropical regions provide greater stability for the abundance of food resources and small variations in environmental conditions (e.g., temperature) compared to higher latitudes, and such factors favor continuous reproduction (Tab. 1). Our study on population structure of *Xiphopenaeus* spp. from Brazil upholds the worldview of latitudinal patterns in life-history attributes for crustaceans, as in numerous other organisms, with more consistent population growth over time, limited life expectancy, and quicker development in tropical and subtropical oceans, than at higher latitudes.

The size at first maturation is essential to determine the minimum size of stock catch, and the overlapping of this size in length distribution curves makes it possible to identify which stratum of the population or stock is most exploited by fishing (Branco et al., 1999). The first maturation lengths differ along the distribution of seabob shrimp (Fernandes et al., 2011; Almeida et al., 2012; Heckler et al., 2013; Martins et al., 2013), therefore, this measure is essential for stock management by defining the minimum catch size and mesh size of the net (Branco, 2005). Morphological maturity of this study confirms the known pattern for penaeid shrimps, in which females have matured later than males and the values are within the expected range for the species (Branco et al., 1999; Almeida et al., 2012; Couto et al., 2013; Eutrópio et al., 2013). Additionally, the size at first maturation found in this study indicate that the exploitation of seabob shrimps in Anchieta is sustainable, since fishing mainly affects the adult stock of the species.

The gonadal development stages (IM, RU, ED, DE) indicate that the seabob shrimp reproduces throughout the year, corroborating the findings of Eutrópio et al. (2013), who analyzed the population of the seabob shrimp in Anchieta. The largest number of females with developed ovaries recorded in the dry season is in accordance with the period found by the previous authors, as well as for regions close to Anchieta (Martins et al., 2013). There are differences in the reproductive period for seabob shrimps in other regions of their distribution, but there is an agreement that the species has a continuous spawning period (Branco et al., 1999; Heckler et al., 2013; Martins et al., 2013). Continuous reproduction is commonly recorded in penaeid shrimps and was described by the tropical/subtropical model of Dall et al. (1990).

This study shows that Anchieta has favorable conditions for the development of seabob shrimps and the local fishing practice has mainly caught adult shrimps, and this is an essential measure to maintain the natural stock of the species. The biology parameters estimated in this study were comparable with the available literature (Branco, 2005; Castro et al., 2005; Santos and Silva, 2008; Fernandes et al., 2011; Heckler et al., 2013; Martins et al., 2013). On the other hand, all of the aforementioned authors sampled large quantities of seabob shrimps to estimate the population parameters of the species in different locations (Tab. 2). Is it really necessary to sample large quantities to estimate population parameters? Our study indicates that it is not necessary, and that with small samples it is possible to study the biology of shrimp. There may be regions where sampling large quantities would be detrimental to stocks, so initial studies like this are necessary. *Xiphopenaeus* spp.

Table 2. Sampling number of seabob shrimp (*Xiphopenaeus* spp.) mentioned in the literature and observed in the present study.

Authors	State	Rig trawl type	Sample number
Branco, 2005	SC	double-rig trawl	6,990
Castro et al., 2005	SP	double-rig trawl	19,065
Santos and Silva, 2008	BA	–	8,114
Fernandes et al., 2011	RJ	double-rig trawl	21,055
Heckler et al., 2013	SP	double-rig trawl	6,470
Martins et al., 2013	ES	–	6,006
Reis Jr., 2019	SE	–	13,035
Present study	**ES**	**otter trawl**	**1,564**

Dashes mean that the type of net was not specified in the study.

are considered overexploited due to the high fishing pressure on the stocks. Therefore, methods that mitigate the impact of catching these crustaceans and allow their study in the natural environment should be taken into account (Valentini et al., 1991; D'Incao et al., 2002; Vasconcellos et al., 2007).

Although studies such as Fernandes et al. (2011) sampled shrimps for three years, resulting in the largest sample size (Tab. 1), the other studies presented analyzed the population of the seabob for 1 or 2 years and usually in monthly collections. Trawling time lasts 20 to 30 minutes with an average speed of navigation at two knots, with vessels ranging from 6 to 15 meters and commonly using double-rig nets. This type of net is used in double trawling and consists of the use of two identical cone-shaped nets. The technique is constantly used by the large commercial fleet along the southeast and south coast of Brazil (https://www.icmbio.gov.br/cepsul/artes-de-pesca.html) and catches large amounts of marine organisms during bottom trawling.

Although it is a commercial species with large landings along the Brazilian coast, and the sampling effort is not a limitation for monitoring the species, evaluating the biology of the species with a reduced number of samples can be essential for conservation. Obtaining data quickly and efficiently for management is essential, and it suffices that the sample is representative of the population. Preliminary analyzes of the present study comparing the amount of shrimp used show that it is possible to obtain robust information on the biology of *Xiphopenaeus* spp. with a smaller sample. Therefore, this study suggests that research be carried out using scaled samples, for example, 300 g, 500 g, 800 g and 1 kg; for comparison with the biological data for the species available in the literature.

In addition, we performed a power analysis that indicated that the sample number from 1000 individuals would be sufficient to obtain the same effect as larger sample sizes, when compared to negligible distance. This theoretical result is confirmed in our study where we used ~1500 randomly sampled shrimp. The results presented here corroborate the estimate obtained in the power analysis and open the way to the possibility of studying the population biology of a species of great commercial interest with smaller sample sizes. Considering the longevity of the seven-bearded shrimp (Fernandes et al., 2011), the information obtained in this study indicates that aspects related to the biology of the species can be evaluated with a small sample size (~1500 individuals) compared to other studies.

Reducing the sampling effort for scientific purposes does not significantly contribute to the conservation of shrimp populations, as in relation to the fishing fleet (a large number of boats towing many hours and many days during the fishing season), the impact of scientific sampling is insignificant. However, applying some strategies to mitigate the sampling effort can reduce the cost of scientific research without losing the quality of the work. In addition, it shows managers the possibility of monitoring with lower effort. That said, three measures are recommended that can be used to mitigate the sampling effort in scientific research related to marine shrimp biology. These are: (1) type of trawl; (2) reduction of trawl time to 20 minutes when the study target is only shrimp, reducing the volume of organisms captured during a bottom trawl; and (3) removal of shrimp directly from the fishing area, representing a part of the shrimp population exploited by fisheries.

In general, the results of the study indicate that *Xiphopenaeus* spp. complete their life cycle in Anchieta, as the sampling carried out captured juveniles and adults in different size classes. The existence of continuous spawning throughout the year is in line with the results of the literature, and the application of spawning as a resource management strategy has been shown to be effective in maintaining stock in Anchieta. All the estimates of the present study corroborate the current knowledge about the biology of the species. Finally, this study gathered important information about the biology of the shrimp *Xiphopenaeus* spp., which allows the use of these data to support management and conservation plans for this shrimp in the region of Anchieta, south coast of Espírito Santo.

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ADDITIONAL INFORMATION AND DECLARATIONS

Author Contributions

Conceptualization and Design: KAF, ACAB. Performed research: KAF, ACAB. Acquisition of data: KAF, ACAB. Analysis and interpretation of data: KAF. Preparation of Figs/tables/maps: KAF. Writing - original draft: KAF. Writing - critical review & editing: KAF, ACAB.

Consent for publication

All authors declare that they have reviewed the content of the manuscript and gave their consent to submit the document.

Competing interests

The authors declare no competing interest.

Data availability

All study data are included in the article.

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